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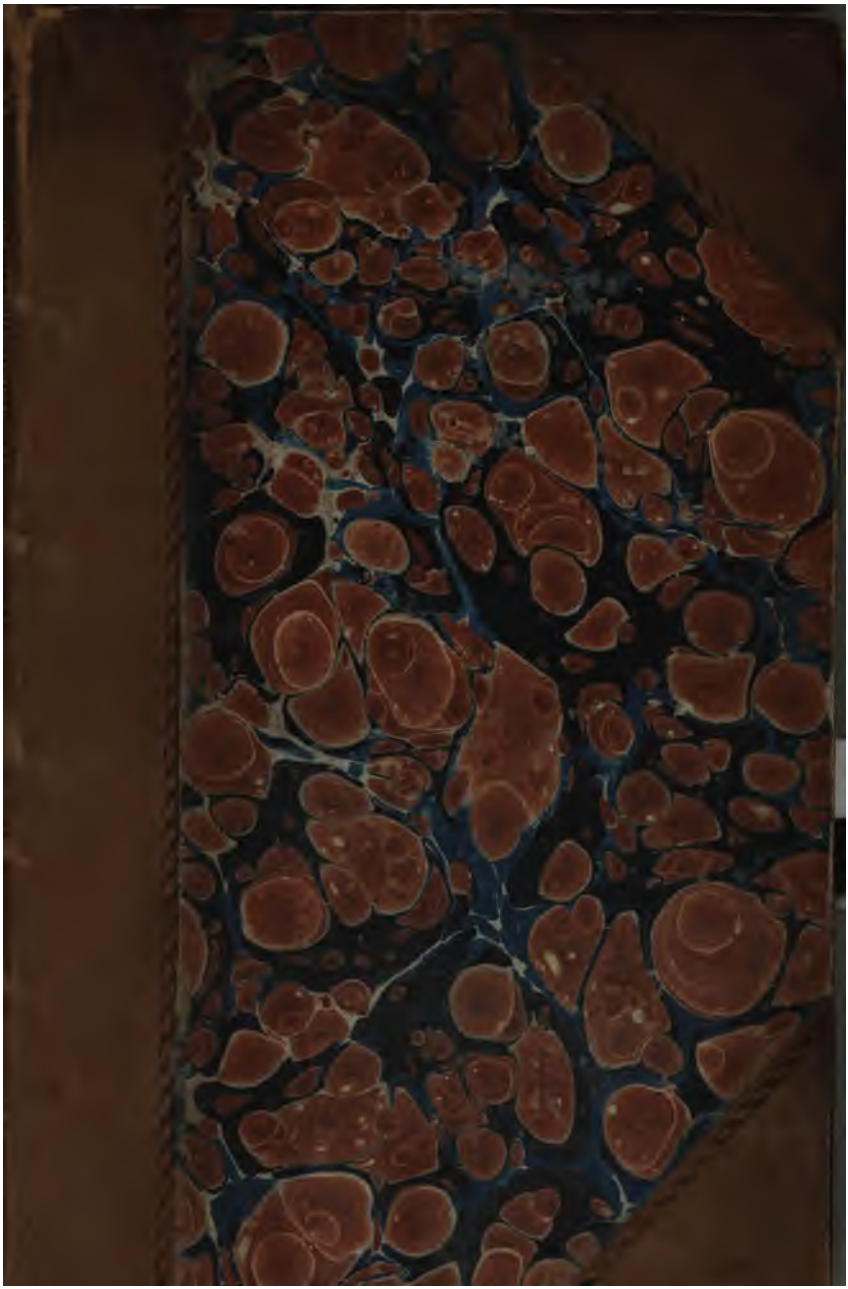

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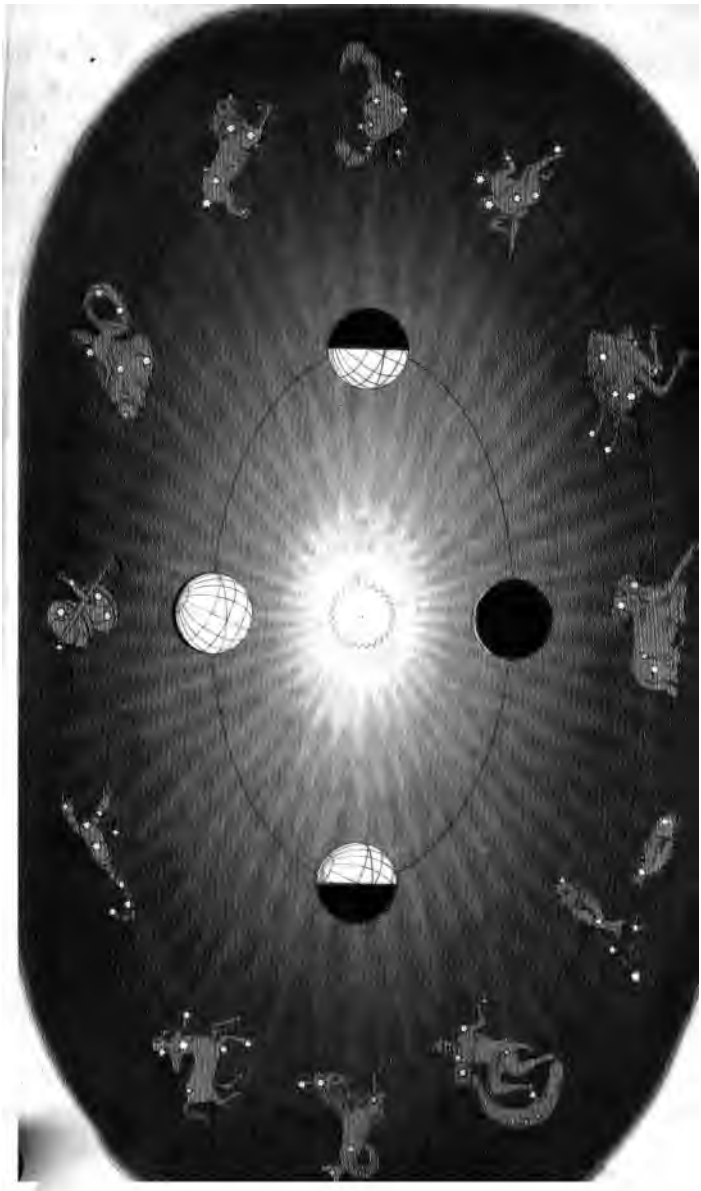
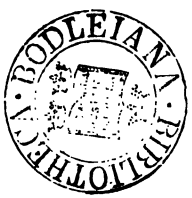


RECREATIONS

IN

ASTRONOMY.



BY

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PREFACE.

AMONG the various objects which engage the attention, and occupy the leisure hours, of those who are favourably disposed to mental pursuits, the works of nature are not always sufficiently estimated and brought into view. The traveller and the historian, the artist and the artisan, offer their various works and productions for the study or recreation of young and old: but they invite attention, for the most part, to the imperfect works of man; and their productions, though valuable in themselves, possess not the intrinsic worth of the more perfect works of nature; nor can they, therefore, produce those ennobling results which the study of the latter is calculated to afford. The works of man bear with them the characteristics of man, and partake of his imperfections: yet, it is natural for us to feel an interest in them, as affording proof of the industry and skill of our fellow-creatures: but the works of nature bear the stamp and impress of the great and perfect Being who made man, and they, consequently, partake of the perfect nature of their divine Author.

Among the numberless objects of creation, which invite our contemplation, and afford overpowering evidence of their divine Creator, there are none more worthily adapted to occupy our time than the STARRY HEAVENS, including a general survey of the arrangement and mechanism of the wondrous system of worlds, of which our Earth forms but a part. We trust, therefore, that the reader, in devoting some of his hours of recreation to the perusal of the following pages, will become the more fully impressed with the feeling which prompted the exclamation of the inspired writer: "The heavens declare the glory of God, and the firmament sheweth his handywork."

It is necessary to state, that the present Volume includes several articles on POPULAR ASTRONOMY, which have already appeared in the *Saturday Magazine;* but, in order to suit the purposes of the present series, those articles have been remodelled, partly rewritten, and considerably extended.

SALISBURY,
December, 1839.

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RECREATIONS IN ASTRONOMY.

INTRODUCTION.

"WHEN I consider thy heavens, the work of thy fingers; the moon and the stars, which thou hast ordained;—what is man, that thou art mindful of him? and the son of man, that thou visitest him?" —Psalm viii., 3, 4.

When the inspired Psalmist gave utterance to these words, he was evidently under the influence of those feelings of awe, wonder, and admiration, which are sure to be excited in every intelligent mind, by the splendid and sublime phenomena presented to us by the heavenly bodies. When we consider the magnitude and the number of those bodies, the immense distances which separate them one from another, the almost inconceivable velocity with which they move, and that those which we can see form, probably, but a very small part of the whole number;—when we revolve these things in our minds, we are naturally brought to reflect on our own insignificance in the grand scheme of creation. If a man, after having applied to himself the vain and self-satisfying appellation of "lord of the creation," were to remember that the glorious sun, and the planets which revolve around it, form but one particular division, class, or system in the

universe,—that the earth is but an humble member of that system, and that he, man himself, is but a moving particle on the surface of the earth,—he may well be expected to give utterance to the sentiments of David, and to wonder how the Great Deity can regard with parental care so humble a member of so magnificent a whole.

But this feeling, as Addison has beautifully shown, arises from the narrow powers of our own minds. We know that our perceptive faculties soon reach a boundary beyond which we cannot pass: we study the laws of Optics, but we know not the nature of Light:—we feel that we live and think, but we know not what constitutes life and thought. When, therefore, we judge of the Great Creator, by our own standard, we are lost in wonder at the vastness and at the minuteness, as also at the countless number of the objects which are under the Divine protection. But when we consider God as an Omnipresent and Omniscient Being, we then admit, indeed, that nothing is too vast, nothing too minute, nothing too numerous, for His notice; that He who could create and arrange the whole, can also watch over and preserve the minutest parts of that whole. Our notions of great and small are derived from our own imperfect experience, and strikingly show the limited scope of our minds. The distance of the sun from the earth is a quantity so immense, as almost to perplex the mind which reflects on it; and yet that distance is small, compared with the distance of the fixed stars:—again, the minuteness of the nerves and smaller blood-vessels of the human body, is such as to require the microscope to aid us in an examination of their structure, and yet there are other entire animals,

endowed with life and powers of motion, which are so minute that the eye cannot perceive them. The words *great* and *small*, then, are for man's use; to the Almighty nothing is great, nothing is small; the revolving planet, and the animalcule whose world is a drop of water, being equally objects of His ever-active care. This divinely-sustaining power of Him, in whom "we live, and move, and have our being," is so obvious, that we may exclaim with the poet Thomson—

> Were every falt'ring tongue of man,
> Almighty Father! silent in Thy praise,
> Thy Works themselves would raise a general voice,
> E'en in the depth of solitary woods
> By human foot untrod;—proclaim Thy power,
> And to the choir celestial Thee resound,
> Th' eternal cause, support, and end, of all!

Nothing is more calculated to elevate the mind, and to display to us the wonders of Creation, than the study of Astronomy. We propose, therefore, to place before our readers a popular view of the elements, which serve for the basis of the astronomer's study. In doing this, we need not have recourse to the mathematical reasonings on which the various statements of the astronomer are founded; but we shall confine ourselves to such a simple explanation of the Mechanism of the Heavens as may pave the way for the study of a more systematic treatise. We trust, therefore, that both those who have, and those who have not, an opportunity of referring to more elaborate works, will not find the following pages devoid of instruction.

CHAPTER I.

GENERAL APPEARANCE OF THE HEAVENS. FORM OF THE EARTH. THE SUN, MOON, AND STARS. RISING AND SETTING OF CELESTIAL BODIES. THE POLE-STAR. PLANETS. COMETS.

Let us suppose a man to be totally ignorant of Astronomy, and to turn his attention from events occurring upon earth, to those which are presented by the heavens. He sees a brilliant and glowing body, the Sun, rise in the east, at from four to eight o'clock in the morning, according to the season of the year. This body gradually attains a considerable altitude in the heavens, and continues to rise until noon;—it then gradually descends, and in its descent, bends towards the west, where it sinks, (apparently below the earth,) some time between four and eight o'clock in the afternoon. The spectator now loses sight of the glorious orb, which does not again become visible for several hours; and when it does again appear, it is not at the point where it escaped from view, but at the opposite side of the heavens, namely, at the point where it first appeared on the preceding day. On watching the progress of the sun, he finds that the path, before noticed, is again travelled over by the luminary, which becomes lost to his view, as before, in the west. A third and a fourth day the same phenomenon occurs; and the question naturally suggests itself to the observer's mind, "Is it the same cheering and dazzling visiter which I see day after day, or are they different bodies, resembling one another, and following one after another?" Were he

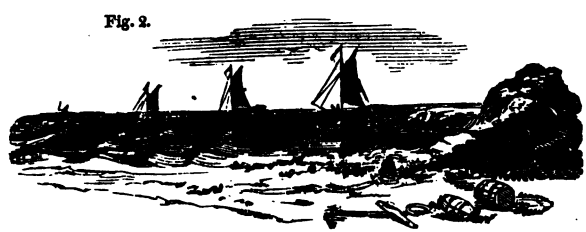
to confine his attention to the occurrences of only a few days, he would, perhaps, think the latter supposition to be correct, viz., that they were different bodies which thus appeared to him day after day. But if he were to continue his observations for weeks, months, years, or the greater part of his life, and to find that the daily appearance of such a body still continued, he could hardly fail to conclude that it was the *same* body which thus so frequently attracted his attention and admiration. "But how?" (he might say,) "do I not see this ruddy disk of light dip into the ground in the west, and appear to me again in the east on the following morning: what becomes of it in the meanwhile?" To answer this question, or to obtain the means of answering it, he would, perhaps, trace more particularly the path which the sun followed from morning to evening, which he would find to be a semicircle, or a curve not differing much from it. If, likewise, he were to take note of the time occupied in these occurrences, he would soon find the time that the sun is above the surface of the earth to be, on an average, equal to the time that it is invisible.

From these two facts, it would be by no means unreasonable to arrive at the conclusion, that the Sun moves in a circle; and that, while he is invisible to us, he is passing round the Earth, in a direction from west to east, at which latter point he arrives at the moment that the observer sees him rise in the morning.

Here a difficulty arises, which, it may well be supposed, would perplex the uninitiated observer. What can be meant by going round the Earth, if the Earth be, as it seems to our eyes, a flat and extended surface of ground, or water, which seems to touch the sky at the

farthest points which the eye can reach:—how then can the sun pass round this? There can scarcely be a more reasonable question, so long as we judge merely by what meets the eye; but, if we extend our observations to certain appearances on the ocean, we begin to see proof that the surface of the water is not quite flat. On land, we have not the means of making a similar observation, because of the intervention of mountains and valleys. The proof that the surface of water is not quite flat is derived from the following circumstance. If we are at sea, on a clear day, and watch the approach of a vessel from a distance, we find that the masts are visible sooner than the hull: we first see the top of the masts; then the whole height of the masts gradually comes into view; and finally, we see the hull. These different appearances of the ship, as it approaches towards the observer, are represented in the following figure. This could not occur if the earth

Fig. 2.



were perfectly flat, because then the hull and masts would come into view at the same time. It matters not what part of the world be chosen as the place of experiment; the result is almost exactly the same everywhere, and the amount of the bending of the surface of the ocean may be illustrated thus:—If we had a

piece of string four miles long, and were to apply both ends to the surface of still water, and could possibly draw the string into a perfectly straight line, the middle of the string would be about sixteen inches below the surface of the water; thus showing that the water is not quite flat.

Thus might be supposed to arise the first conjecture that the Earth is round, like a ball; a fact which was clearly proved by Captain Cook, who performed a voyage completely round the earth, about the year 1769. He left a given spot, and arrived again at that spot by an opposite course. This had been also done by the Spaniards, about the year 1520. There is an abundance of proof, derived from other sources, that the Earth is a globe; but those will open upon us more plainly, as we advance.

We have hitherto endeavoured to trace what would probably be the feelings and opinions of one who, without previous instruction in Astronomy, should note the appearances presented by the Sun. But that golden orb is not seen to be a solitary inhabitant of the sky: another luminous body about as large in apparent size as the Sun, would soon attract the notice of the gazer. He would see it rise in the east, soar aloft, and then sink in the west. After the lapse of a few hours it would again appear in the east, attain a height from which it would again descend, to sink as before in the west. The train of reasoning which would lead the observer to conclude that the Sun revolved round the Earth, would lead him to a similar conclusion regarding the Moon. But here the resemblance terminates. The Sun always presents a perfect circle to the eye of the observer day after day, and month after month; but a few even-

ings suffice to show that such is not the case with the Moon: at one time a crescent only is seen, whose hollow side is towards the left of the observer; at another time the hollow side is towards the right: the crescent sometimes enlarges to a perfect circle; which at other times contracts from a circle to a crescent. If, then, the Moon be a ball or globular body, shedding light upon the Earth, there is great difficulty in conceiving what can occasion the change in its apparent shape; but, if we were to consider the Moon to be an opaque or non-luminous body, we should find the means of explaining the change in its apparent figure, by supposing that the Sun shines upon the Moon, and that it is only by the reflection of the Sun's light from the Moon that the Moon becomes visible to us. If we place a large round ball on a table, in a place where the Sun is shining, we shall see the ball more or less illuminated, according to our position with regard to the ball and the Sun: in one position, the ball will appear to be equally divided by a boundary line, into two semicircles, one illuminated and the other in the shade: in another position, the illuminated portion will be only a crescent, all the rest being shaded: from another point again it will all appear illuminated, except a small crescent of shade. If the observer watch the relative positions of the Sun and Moon, he will see that the shape of the bright part of the Moon depends on its relative position in respect of the Sun; just as the bright portion of the illuminated ball depended on the position in which he viewed it.

We should in this way find the means of accounting for the change in the shape of the Moon. We shall, by and bye, show that these suppositions are really true. But another point would attract the notice of

the observer, independently of the change in apparent form. If the two brilliant bodies, the Sun and Moon, were observed to be near each other on a certain day when the latter appeared as a thin crescent to the left of the Sun, they would be seen the next day further removed, and on the following day, at a still greater distance from each other: if, therefore, the motion of the Moon round the Earth be admitted, it is necessary to suppose that motion to be slower than the Sun's motion round the Earth.

But in addition to the glowing light of the Sun and Moon, a glittering assemblage of smaller bodies meets the eye of the observer: a crowd of little spangles adorns the sky when the Sun has left it, and softens the dreary darkness which results from his absence. These stars are seen to resemble the Sun and Moon in the circumstance of rising in or near the east, attaining a certain altitude, and setting in the west; from which circumstance the observer infers that the stars, like the Sun and Moon, revolve round the Earth. But, by a careful attention to different stars, he would find that the same remark does not apply to all. Those which rise exactly in the east, set exactly in the west; those which rise to the south of east, set south of west; and many which rise somewhat north of east, set somewhat north of west; but in looking northward he sees stars which appear neither to rise nor to set, but which perform a complete circle round a particular point of the heavens. For example,—there are seven stars, which, to most persons who pay any attention to the appearance of the heavens, are known under the name of the Great Bear. These stars never rise or set to an inhabitant of London. If they become invisible, it is either

because clouds obscure them, or the superior brilliancy of the Sun drowns their comparatively feeble light. The same may be said of five conspicuous stars known by the name of Cassiopeia's Chair.

If we watch the progress of these stars, and others in their vicinity, we shall find that they describe a circle round a star called the Pole-star. The position of this star we shall find to be nearly this: if we suppose the distance from the north point of our horizon (which is the line in which the surface of the earth appears to touch the sky) to the zenith (which is the point immediately over our heads) to be divided into five equal parts, then at about the height of three of those parts from the earth, will be seen the Pole-star.

All this would seem to show to an observer, that the Pole-star is the end of an axis round which all the stars revolve, and that the reason why we cannot see the whole circular path of any stars except of those in the vicinity of the Pole-star, is, that they pass round under the Earth during a part of their journey, and are therefore concealed from our view. Those stars which are further removed from the Pole-star describe larger circles than those which are nearer, while the Pole-star is almost stationary. This is exactly what takes place when we see a wheel turn round; the axle remains in one spot, but any particular point on the outer edge of the wheel describes a larger circle than that which is described by any point between the axle and the circumference.

If we consider the Pole-star to form one end of the axle or axis round which the stars revolve, then it is obvious that there must be an opposite end of the same axis, in the contrary direction. If then we turn to-

wards the south, with the expectation of seeing such a point, we shall find that it will not be realized; for none of the stars in that quarter are seen to describe circles; for they all rise and set. Still, however, the semicircles or portions of semicircles, commonly called arcs, which they describe, appear to have a common centre, which is some distance below the horizon; and this centre may be considered as the southern end of the axis before spoken of.

If we suppose the observer to have arrived at this amount of information respecting the stars, he will be prepared to notice the uniformity of the positions of the stars with respect to one another. The Great Bear, for instance, whether it be under or over the Pole-star, or at the right or the left of it, will always have its seven principal stars at the same relative distances from each other. The changes which take place in the distance of the sun from the moon, would lead to the opinion that these revolve round the earth in unequal times; and by similar reasoning, the constant maintenance of the same distance between any two stars would seem to imply that the stars revolve in equal times.

The seeming myriads of stars which present themselves to the notice of the observer all appear to follow this rule, of remaining at the same relative distances from one another, with very few exceptions. These exceptions are, indeed, so few, that a constant watching of the same part of the heavens for a considerable period would be necessary to determine that a star had actually changed its place relatively to other stars. There have, however, been discovered at different times,

ten stars, more or less brilliant, which change their relative distances from one another, and from other stars. These we know by the name of Planets; and by a careful attention to their movements, it is seen that each one travels in a curved path among the other stars, and returns again nearly to the point from whence it set out.

At intervals, again, star-like bodies of another order present themselves, whose progress among the other stars is more rapid than that of the planets; and which, at a period more or less brief, vanish altogether from the view of the observer, and do not return till after a long absence. To such bodies we give the name of Comets.

Such, then, are the equally sublime and fascinating appearances which present themselves to the eye of an observer, when that eye is directed towards the heavens. That the invigorating and fructifying warmth and light shed by the sun,—the serene, quiet light of the moon,—and the diamond-like glittering of the stars,—should invite men to a study of the laws which, under their Divine Creator, govern the motions of such exquisite globes of light, is what we are not only prepared to expect, but fancy that we should feel disappointment in finding it otherwise. Man is not, by nature, the cold heartless being who can let such beauties pass unheeded; and if he approach the study with the humility which true self-knowledge is calculated to engender, he becomes more and more able to appreciate the surpassing grandeur and power of the great Being who made and who rules all. Well, indeed, may we direct our attention to the phenomena which we have

briefly described, and to which Milton so exquisitely alludes in the following lines:—

First in his East the glorious lamp was seen,
Regent of day, and all th' horizon round
Invested with bright rays, jocund to run
His longitude through Heaven's high road; the gray
Dawn, and the Pleiades* before him danced,
Shedding sweet influence: less bright the moon,
But opposite in levell'd West was set
His mirror, with full face borrowing her light
From him; for other light she needed none
In that aspect, and still that distance keeps
Till night; then in the East her turn she shines,
Revolved on Heaven's great axle, and her reign
With thousand lesser lights dividual holds,
With thousand thousand stars, that then appear'd
Spangling the hemisphere: then first adorn'd
With their bright luminaries that set and rose,
Glad evening and glad morn crown'd the fourth day.

Par. Lost. b. vii.

* Seven small stars clustered together in the constellation Taurus. These stars rise with the sun about the time of Spring, and our poet, in this passage, intimates the old and common opinion that the Creation took place in the Spring.

CHAPTER II.

THEORIES TO EXPLAIN THE MOTIONS OF THE HEAVENLY BODIES. PTOLEMY. COPERNICUS. TYCHO BRAHE. NEWTON. A POPULAR VIEW OF THE THEORY OF GRAVITATION.

In very early ages, before Europe occupied a page in the history of nations, the phenomena of the heavens were studied with great attention by several nations of the East. The Chaldeans, the Indians, the Chinese, and the Egyptians, have all left evidences of the industry and ingenuity with which their observations were conducted. They constructed observatories, — invented instruments for observing and measuring with accuracy, —separated the stars into different groups, called Constellations, for the facility of finding any individual star,—gave particular names to most of the moving stars or planets, and noted the period which each took to move through its apparent path in the heavens; and, in many other ways, the ancients helped to lay the foundation of that mass of astronomical knowledge which the men of later ages have brought to more maturity.

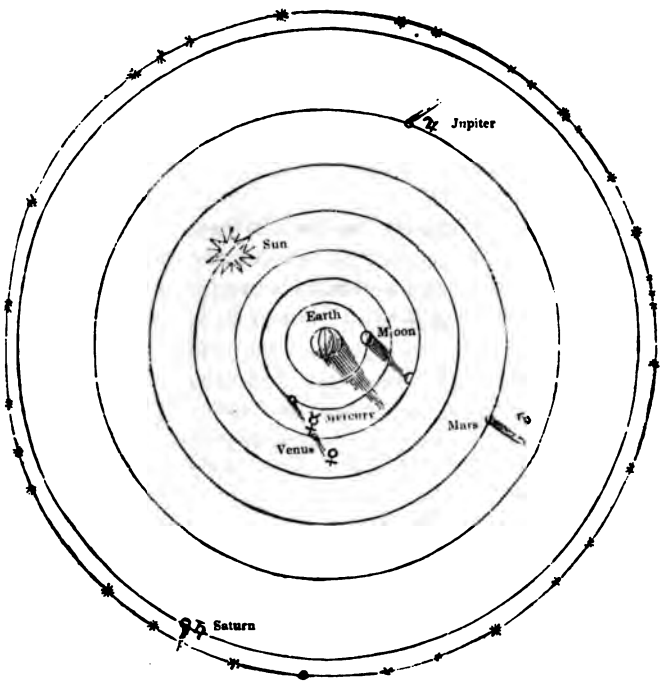
Various opinions were formed respecting the motions of the Sun, Moon, and stars of all kinds, both with reference to one another, and also to the Earth; but the first theory which had attained a name and an importance in the early ages of the world, was that of Ptolemy, a distinguished Egyptian astronomer, who lived about one hundred and thirty years after the birth of Christ. He conceived that the various bodies which had been

distinguished by the appellation of " the heavenly host," were disposed in the order represented in the annexed diagram.

He supposed, according to the popular opinion, that the Earth was fixed as the centre of the universe, and that the Sun, Moon, Planets, and Stars, revolved round it in the following order; namely—the Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn; the Moon being the nearest, and so on; exterior to all of which, he supposed that a great concave sphere in which all the stars were fixed, kept on revolving round the Earth. From the early history of Astronomy, we learn that before the time of Ptolemy it had been conjectured by some that the Earth passed round the Sun, and not the Sun round the Earth; but the difficulty of believing a statement so contrary to appearances and to the evidence of one's physical senses, led to the rejection of this opinion; and although it was afterwards found to be correct, yet nearly two thousand years elapsed before such a theory was generally admitted by philosophers.

After Ptolemy had promulgated the theory which bears his name, he found that there were certain difficulties which followed from the adoption of it. He conceived that the seven bodies mentioned before which revolved round the Earth, moved in the same general direction from west to east. But on watching the progress of some of the planets, he found that they did not appear to travel uniformly round the Earth, but seemed to have, at certain times, a retrograde or opposite motion, with reference to the other planets; while at other times they seemed to be stationary. To account for this, he was obliged to suppose that those

Fig. 3.



THE PTOLEMAIC SYSTEM.

planets did not revolve in a perfect circle round the Earth, but that they described a peculiar path called an *epicycloid*, of the nature of which some idea may be formed from the following illustration:—If we had a large coach wheel, and by any contrivance could make a smaller wheel roll round the outside of it, at its circumference, then any particular point on the small wheel would describe that curve which is called an epicycloid: the axle of the small wheel would describe a perfect circle, but it is easy to see that any point on the edge would not describe a circle. Ptolemy was obliged to multiply these epicycloids to a most perplexing extent, in order to account for the various appearances of the planets. It is to this circumstance that Milton alluded, when he spoke of the shifts and difficulties which beset the progress of those who build their opinions on a wrong foundation:—

> When they come to model Heaven
> And calculate the stars, how they will wield
> The mighty frame; how build, unbuild, contrive,
> To save appearances; how gird the sphere
> With centric and eccentric scribbled o'er,
> Cycle and epicycle, orb in orb.—*Par. Lost.* b. viii.

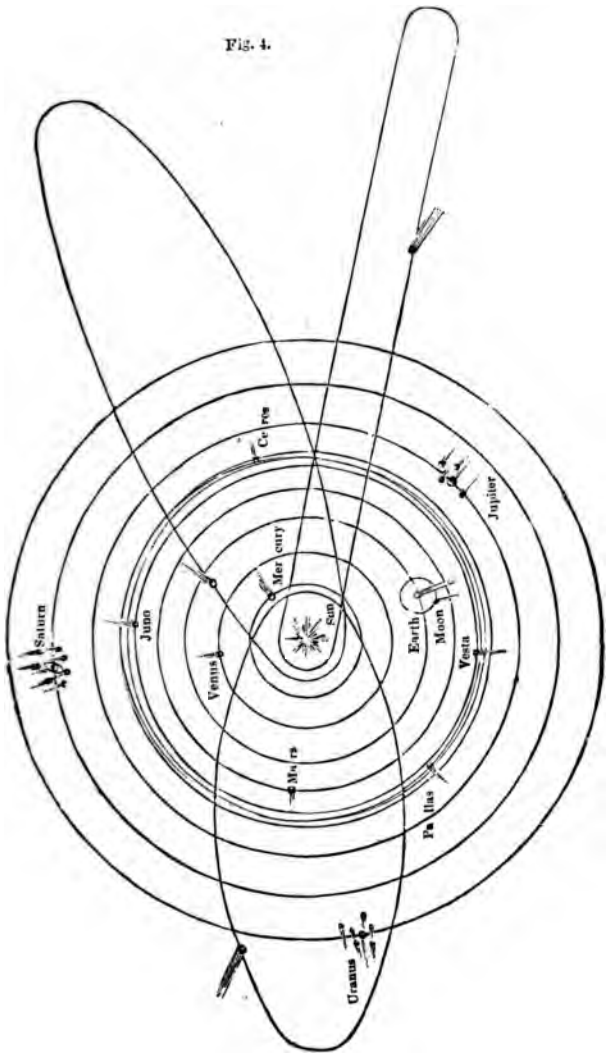
There is nothing which more beautifully shows the power and force of truth, than the embarrassments which retard the progress of those who do not take truth for their guide. In religion, in morals, in science, he whose steps are guided by the light of truth, can arrive, by a short and pleasant path, at results which others can scarcely obtain by a complex and wearying track. Thus Ptolemy was forced to assume the existence of much unwieldy machinery in the scheme of the heavens, in order to account for those motions which

are most simple and beautiful; this was because he placed (in his own imagination,) the earth in the midst of the heavenly bodies, all of which were made to revolve round it.

Great as were the difficulties which attended the adoption of the Ptolemaic system, it yet retained its ground, with some slight modifications, until the time of Nicholas Copernicus, an eminent astronomer, who was born at Thorn, in Polish Prussia, in 1473. This distinguished individual perceived the unreasonable results which follow from the theory of Ptolemy. That all the planets, the Sun, the Moon, and all the stars and comets, should revolve round the Earth, seemed to him much more unnatural and complex than that the Earth should revolve on its own axis, and move in an orbit round the Sun. All appearances of the heavenly bodies can be explained with much greater ease and simplicity by the latter supposition than by the former; and Copernicus was thus led, after the study of forty years, to the adoption of a theory which had been advocated by Pythagoras and Thales of Greece, five or six hundred years before the time of Ptolemy.

Figure 4, is a representation of the solar system, according to the theory of Copernicus. In this system the sun, the glorious source of light and heat to us, is placed in the centre. Round him the planets revolve in the following order:—Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Since the time of Copernicus, five more planets have been discovered, namely, Uranus, Pallas, Vesta, Juno, and Ceres. In order to account for the phenomena presented by the Moon, Copernicus assumed, (what has since been confirmed,) that the Moon has a twofold motion,—round the Earth and

Fig. 4.



THE SOLAR SYSTEM.

round the Sun; a small circle, therefore, surrounds the Earth, which circle represents the path of the Moon round the Earth, while the Earth and the accompanying Moon together revolve round the Sun. This figure of course represents the Copernican system with the addition of the five planets since discovered. The circles represent the orbits of the several planets; that is, the paths in which they travel in their progress round the Sun. The distances of these circles from the centre at which the Sun is placed, could not conveniently be in the same proportion one to another, as the real distances of the planets are respectively from the Sun, because the innermost orbits would be too small to be conveniently seen. The real proportions, however, which exist between the distances of the planets from the Sun, admit of being easily understood. For instance, the Earth, (as we shall hereafter explain more fully,) is about ninety-five millions of miles from the Sun. If now we call that distance 1, the distances of the other ten planets from the Sun, will be represented by the following numbers, with sufficient nearness for our present purpose.

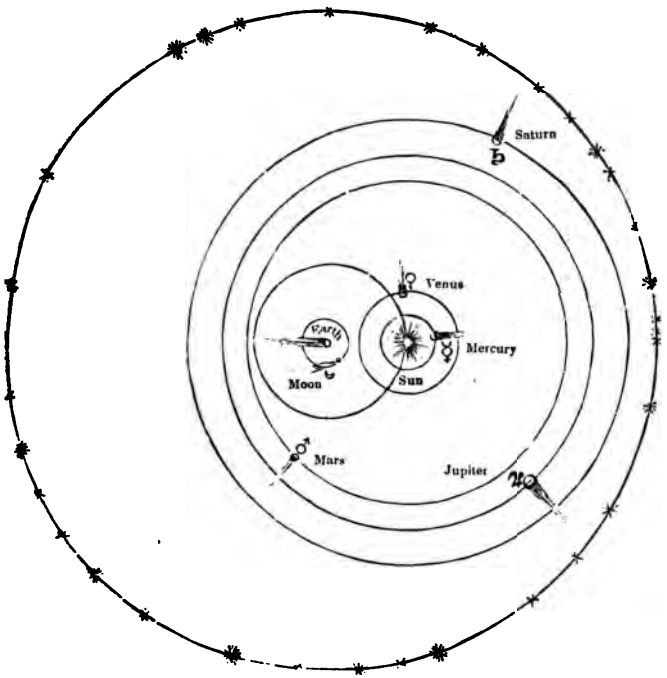
Mercury	$\frac{2}{5}$
Venus	$\frac{3}{4}$
Earth	1
Mars	$1\frac{1}{2}$
Vesta	$2\frac{1}{3}$
Juno	$2\frac{2}{3}$
Ceres	$2\frac{2}{7}$
Pallas	$2\frac{2}{7}$
Jupiter	$5\frac{1}{5}$
Saturn	$9\frac{1}{2}$
Uranus	$19\frac{1}{5}$

There was an astronomer of very great skill, who lived about the same time as Copernicus, who thought that a mean might be struck between the theories of Ptolemy and Copernicus, by which the favourite idea of a celestial revolution round the Earth should still be retained, and so concession might be made both to the growing authority of science, and to the persuasion of men's senses. This astronomer was Tycho Brahé, who was born in 1546, at Knudstrup, in Denmark. The system advocated by him, and which is named from the inventor the Tychonic system, is represented in the annexed diagram.

In this system, which was published about the year 1586, the Sun is considered as a centre, round which five of the planets revolve; namely, Mercury, Venus, Mars, Jupiter, and Saturn; while, at the same time, the Sun himself, with all those planets, revolves round the Earth. It certainly appears strange, that a man of such eminent abilities as Tycho was, should have preferred this ponderous arrangement to the more simple theory advocated by Copernicus. After the death of Tycho, his theory gradually sank in the estimation of philosophers, who found, in the arrangement advocated by Copernicus, the means of explaining celestial phenomena by less complex reasonings than by the theories either of Ptolemy or of Tycho Brahé.

Here, then, we arrive at an important part of our subject; that there are, as we shall hereafter show more clearly, immense bodies revolving in orbits which measure millions of miles across. The appearances presented to the eye lead to an opinion that these bodies revolve round the earth; but a further inquiry into the accompanying circumstances, have led men universally, at the

Fig. 5.



THE TYCHONIC SYSTEM.

present day, to conclude that the Earth and the other planets revolve round the Sun.

What then can keep these splendid bodies in motion? How did they first begin to move? And why do they revolve round the Sun instead of moving in a straight line? These questions naturally occur to our minds, for our humble faculties can give us but a faint idea of the powers necessary to keep such immense masses in motion. If we see a carriage passing with great rapidity along a railway, we can account for its motion, by tracing the action of steam-pressure upon a piston; which by connecting machinery makes the axles of the wheels revolve, and thus sets the whole vehicle in motion. If we see a carriage passing along the street, we can assign a cause for its motion, by the muscular efforts of the horse which is attached to it. If a ball be shot from a cannon, its flight is so rapid as to render it invisible to us, but we can account for its motion by considering that a quantity of gunpowder, small in bulk, suddenly enlarges to about two thousand times its former dimensions, by being converted into gas, when heat is applied; and that the endeavour to obtain two thousand times as much room as it before occupied, acts with such pressure against the ball as to force it out with fearful velocity. All this we can understand, because we can trace the progress of the occurrences step by step. But when we turn to the heavens, we are lost in wonder! Our means of judging admit of no such details of comparison as those which before assisted us; and we are brought to the conclusion that the Almighty, for his own wise purposes, impressed upon the heavenly bodies those motions which we know they possess,—which we can calculate

and measure,—but the origin of which we can here never know.

But ought this circumstance to prevent us from studying the nature and extent of the motions impressed upon these glorious bodies? Is it presumptuous in us to endeavour to become acquainted with the laws which, once known, will give us additional proofs of the wisdom and power of the Divine Architect of the heavens? Assuredly not! The origin of those movements we know not, but the study of the nature and direction of them is a noble and fitting employment for the human mind.

In the century following the age of Copernicus and Tycho Brahé, there sprang up a genius, who was destined to add more to the amount of human knowledge in this path than any one, perhaps, who had previously existed. This was Sir Isaac Newton, who was born in 1642, at Woolsthorpe, in Lincolnshire. This distinguished man displayed from boyhood an ardent love for the study of the natural phenomena around him. When a child he made clepsydras, or clocks which told the hour by the descent of water, through an orifice at the bottom of a vessel. He also constructed a windmill, which was worked in part by a mouse placed inside. As he grew towards manhood, his soaring mind directed itself to the sublime phenomena presented by the heavens, and to the nature and composition of light. That part of his career which more particularly concerns us at present, we will now consider.

When Newton was about twenty-three years of age, he was forced to leave Cambridge where he had been residing, on account of the appearance of the plague

in that town. He retired to Woolsthorpe, where, sitting one day in his garden, he saw an apple fall from a tree at his feet. The falling of an apple might have been noticed often enough; but Newton's searching mind directed itself to this inquiry: "Why does the apple fall, when it is loosened from the tree?" Some may laugh at such a question,—some have laughed at it,—and yet the only answer which the laughers could give, would be, "Because it is the nature of things to fall, when unsupported." This vague explanation did not satisfy the sagacious Newton. He set himself to consider the nature of the occurrence which had attracted his notice, and of others similar to it, and he finished by framing that train of opinions which, under the name of the Theory of Gravitation, laid the foundation of all correct knowledge of the motions of the heavenly bodies, and which is now received by all who deserve the name of philosophers.

> All intellectual eye, our solar round
> First gazing through, he by the blended power
> Of gravitation and projection saw
> The whole in silent harmony revolve.—THOMSON.

We shall here find it convenient to consider the nature of this force of gravitation, and will endeavour to do so in the simplest way possible. Every particle of matter in the creation has a tendency to attract, or draw towards itself, every other particle, however distant it may be. We know not what this attraction is; we can therefore only judge of it by its effects. This attraction is of different degrees of force according to the size or density of the attracting body. A small loadstone or magnet will take up a little key, whereas a larger magnet will take up a larger key: so it is with

attraction; a lump of lead weighing one pound only, attracts a distant body with half the force which is exerted by another piece of lead weighing two pounds. Again, the force of this invisible agency is subject to variation, with respect to the distance between the attracting and attracted bodies. If a mass of lead be the attracting body, and two equal-sized bodies be at some distance from it, the one which is the nearer of the two will be attracted with greater force than that which is further removed. The diminution of attractive power from increase of distance is much more rapid than from the lessening of the size of the attracting body. For instance, if any mass of matter attract another mass with such force as to make it move through twenty feet in a second of time; then, if the first mass be removed to double its former distance, the strength of the attraction will be so much weakened, that the second body will move only five feet in a second, or with one-fourth of its former rapidity.

These simple principles, when applied to such immense bodies as the planets, produce results of a gigantic kind. It may be asked, "If a pound of lead will attract a piece of cork more strongly at the distance of one than of two feet, how is it that we cannot see the proofs of such a fact in practice?" The reason is, that the Earth itself forms such an enormous mass of matter that it completely neutralizes the effects of the comparatively small bodies at its surface. In strict truth, if an apple be suspended from the branch of a tree, it tends to attract the Earth upwards to meet it; but the attraction of the Earth for the apple is so incalculably more powerful, that the moment the apple is loosened from the tree, the Earth draws it down to

meet it, and that is what occurs when we say that the apple falls. Suppose that, instead of an apple, a mass of lead weighing a thousand pounds, were for a moment suspended in the air; the lead would tend to attract the Earth upwards towards itself with much greater force than the apple had done: but still the Earth's attraction would so completely overpower the lead, that it would be drawn down to the Earth; while the latter would rise to meet it by a quantity, wholly inappreciable by mortal sense, though not by computation.

But let us now suppose a body placed in the universe, equal in size to the Earth, but at some distance from it. Here we perceive that there is no reason why the Earth should attract the other body more strongly than the latter attracts the Earth; accordingly, if they were both free to move, they would naturally approach towards each other, each one moving through half the distance which separated them. If, therefore, we were to suppose that the universe contained many such bodies, each as large as the Earth, each one would attract all the others, with a force varying only as the several distances varied. But if one body were very much larger than any of the others, it would attract each of the others more powerfully than itself could be attracted; and would not, therefore, have to move through so great a distance to meet any of the other bodies, as they would have to move through, in order to meet it.

All this admits of being impressed upon the mind with tolerable clearness, so long as we consider the bodies to be in the first instance stationary, and then receiving an impulse. But how can we explain the curved path which each of the heavenly bodies de-

scribes in its progress through space; and why do not all the planets get close together by virtue of the attraction which draws them one to another? These questions we cannot answer without a previous attention to other particulars, which we must shortly explain.

If we stand at the top of a high tower, and throw a stone forward to the ground, we shall find that the stone will not proceed on in a straight line, but that it will soon assume a bending path and approach towards the earth. The direction in which this bending occurs, is such as to bring the stone to the earth in a more perpendicular direction than it had when it set out. Now the reason why the stone is thus forced to change the direction in which it first began to move, is because the Earth attracts it and hastens its descent. If we suppose it possible that a hole could be bored through the Earth from side to side, we should find the mass of matter would be more accumulated in the direction which passes through the centre of the Earth than in any other direction; and as bodies attract other bodies in proportion to their mass of matter, we see reason to believe that a falling stone is attracted more powerfully towards the central direction of the Earth, than towards any other part. When, therefore, the stone has left the hand, it gradually tends to a direction perpendicular to the surface of the Earth, or it gets into a direction which, if continued, would lead to the centre of the Earth.

Now if there were no such force as gravitation, the stone would proceed in the same straight line in which it was first propelled. If it were thrown upward from the surface of the Earth, it would continue to travel

upwards, without ever again descending to the Earth. Here we should remember that there is in nature no such thing as *up* and *down;* but that *up* means simply a departure from the centre of the Earth, *down* an approaching towards that centre.

We all know with what amazing velocity a cannon-ball moves, after it has left the mouth of the cannon; yet it soon begins to decline towards the Earth, whether it be originally shot from the cannon in a horizontal or in an upward direction. But still the curvature of its path towards the Earth is much less rapid than in the case of the stone, because the latter moved so much more slowly. The mortar in St. James's Park can propel a bomb to a distance of about four miles, before the bomb will fall to the Earth; whereas a stone thrown by a very powerful arm would certainly fall to the ground within a few hundred yards. Suppose now that it were possible to increase to an indefinite extent, the velocity with which a cannon-ball would move; say that it should travel ten or twenty miles before it touched the ground; a greater velocity would carry it one hundred miles before it fell: and we may go on in the same train to any extent we please, always bearing in mind, that the quicker the body moves, the greater distance will it travel before it falls to the ground. Now, if we assume such a velocity that the ball would travel twenty-five thousand miles before it fell to the earth, we shall arrive at a very curious result. The diameter of the Earth is almost eight thousand miles, which gives, for the circumference, about twenty-five thousand miles. The ball would, therefore, have gone completely round the Earth before it fell to the ground. If the velocity were still greater,

it would not reach the ground at the completion of this circuit, but would go on to describe part of another revolution round the Earth. When this condition is once attained, the ball might, by a due increase of the projectile force, continue to revolve for ever about the Earth, and we should thus have a cast-iron satellite moving around us.

Let not the reader smile at the absurdity of supposing a cannon-ball to travel twenty-five thousand miles; for it will lead us to important results. If we suppose that the Sun were stationary in the universe, and that a body very much smaller than the Sun were to be projected with immense velocity, in a direction at right angles to a line joining the Sun and the other body, then the latter (which would proceed in a straight line if the Sun were not present), is drawn by the Sun into a curved path, the concave or hollow side of which is always towards the Sun. If the velocity with which this body were propelled were below a certain limit, it would move in a spiral which would gradually end at the Sun himself, to which, therefore, the body would fall: if the velocity were beyond a certain limit, the body would describe a spiral round the Sun, but gradually receding from it, and thus would continue through infinite ages to recede further and further from the Sun: but if a certain velocity, of a corresponding ratio with the attractive power of the Sun, were imparted to this body in the first instance, it would move constantly round the Sun, arriving at every revolution at the point from whence it started.

We are now in a condition to explain in some degree how we are to regard the motions of the planets round the Sun. When the Almighty had created the various

bodies which compose the universe, He exercised His infinite power and wisdom by imparting to them various velocities of motion. The Sun being made very much larger than all the planets put together, exerted a more powerful attraction on them than they could exert on him; consequently, the planets were drawn towards the Sun out of their original paths, and made to revolve round the larger body. But how shall we sufficiently admire the exquisite skill with which the various velocities were adapted to the size of the various bodies! What parallel can we find in the poor and imperfect works of man, to that surpassing power of adjustment by which the velocities of the planets are regulated! The Earth moves some hundreds of thousands of miles in a single day; and yet, if her velocity were to deviate by a small fraction, either more or less, the earth would, in the first case, gradually recede from the Sun, and never again approach near him; and in the second case, it would approach to, and fall upon, the Sun. It is when such results as these are obtained, that science enables us to appreciate the striking truth, that man's efforts, even in his proudest moments, are but poor and humble attempts to follow after, or to imitate, that which the Great Being performs with such boundless perfection. We applaud, and we give rewards to the man, who can make a chronometer which will be accurate within a few seconds in the year; and well may we do so, for it is a signal instance of human industry and ingenuity to produce such an instrument. Yet a mere fraction of such an error in the movements of the bodies composing the solar system, would be fatal to its stability. Truly wonderful, indeed, is it, that the eleven planets should revolve round the Sun in periods differ-

ing greatly one from another, and at such various distances from him; and yet, that each one should have a velocity so exquisitely adjusted to its size and position as to bring it precisely round to the same point after every entire revolution round the Sun. The Sun, then, the golden magnet which thus draws all the other planets towards itself, is surrounded with whirling worlds, which borrow their light from him and share it with one another. Well might the poet of the Seasons exclaim—

Thou, O sun!
Soul of surrounding worlds! in whom best seen
Shines out thy Maker! May I sing of thee?
'Tis by thy secret, strong, attractive force,
As with a chain indissoluble bound,
Thy system rolls entire: from the far bourne
Of utmost* Saturn, wheeling wide his round
Of thirty years, to Mercury, whose disk
Can scarce be caught by philosophic eye,
Lost in the near effulgence of thy blaze.

* Thomson had written this before the year 1730; and the planet Uranus was not discovered until 1781.

CHAPTER III.

FORM OF THE ORBITS OF THE PLANETS, AND THEIR MOTIONS THEREIN. MOTIONS OF COMETS AND SATELLITES. GENERAL VIEW OF THE SOLAR SYSTEM.

Our remarks hitherto have been so expressed as to lead to the conclusion that the planets move in perfect circles round the Sun at all times, and under all circumstances. Such, however, is not strictly the case. The paths which they describe are oval or elliptical. Most persons know the form which is meant by the term "oval." If we hold an egg in the hand, and look at its outline, it will give a near approach to this form: and, indeed, the word *oval* is derived from *ovum*, the Latin for *an egg*. Such, then, is the form of the paths in which the planets move. Now we may inquire whether the Sun is exactly in the middle of this oval, or near either end of it. To this it must be answered that the Sun is not precisely in the middle, but that he is a little nearer to one side than the other. It will be useful to give an idea of the position which the Sun occupies. Suppose A B (fig. 6) represent the orbit or path in which a planet (such as the Earth) moves round the Sun. (We have made this a larger oval in proportion than the Earth's orbit really is, in order that our meaning may be more conspicuous.) There are two points F and S (called *foci*, plural of the Latin word *focus*, signifying *a fire-place*), which have

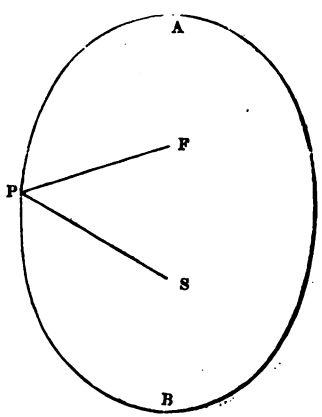
peculiar properties. If we stick a pin in each of the points F and S, and fasten the two ends of a bit of thread to them, (taking care that the thread is just long enough to reach to any one part of the circumference, as at P,) we shall find that we shall be able to make the thread exactly touch every other part of the oval, by stretching it out; but that we cannot make it extend beyond the oval in any direction.

Now it is in one of such points F S that the Sun is situated, in the Earth's orbit. The oval, if we could possibly see it at once with the eye, would scarcely appear to us to deviate from a circle: it being rather a round, not a long oval. We here speak only of the Earth's orbit, but the same remark applies to the orbits of all the planets, which orbits are all more or less oval. We use the term *oval* in preference to the term *elliptical*, because it is more familiarly known; the meaning of each is, however, the same.

We may now be asked, whether the planets move equably in every part of their orbits,—that is, If a planet move at the rate of so many miles in an hour at one part of its orbit, will it move with the same velocity at another part? This question, on account of the oval form of the paths in which the planets move, must be answered in the negative. They do not move equably in different points of their orbits. Suppose that in the following figure, the point S were like the axle of a wheel, and that twelve equidistant spokes, or radii, reached from it to the boundary of the oval, then the Earth, in passing by the end of each spoke during her revolution, would not pass from one to another in exactly equal times, but would take a longer time to pass from spoke to spoke at one part of her revolution

than at another. But now let us suppose, that the *time* which the Earth takes to revolve round the Sun be divided into twelve equal parts, and that we draw a spoke from the axle, or the point S, to the boundaries between all the twelve spaces respectively passed over by the Earth in those equal times; then it will be found that the open space between any two adjoining spokes, measures exactly the same number of square miles at every part of the orbit. The spokes towards the end A

Fig. 6.



will be closer together than those towards B, but they will at the same time be longer, so that the excess of length precisely compensates for the deficiency in width. Here is another instance of the admirable adjustment which is observable in the motions of the heavenly bodies. The orbits of the planets are all oval, and differing in the form of the oval; yet the law which we have just stated is found to be constant. The more the orbit

approaches to what we may term a long oval, the greater is the difference between the lengths of the spokes towards the two ends. Yet in every case, a disagreement in length is made up by a reverse disagreement in the openings between them, so that these areas or openings are all equal. We have been anxious to avoid every appearance of scientific difficulty in these details; but we will just mention that those who may be able to consult larger works on Astronomy, will find this law thus expressed; that "a planet always describes equal areas in equal times."

Those fleeting and transient visiters, comets, are too seldom in sight to afford the means of making such correct observations of the nature of their orbits, as have been made with respect to the planets. We shall, by-and-bye, have to speak individually of several comets, which have appeared at various times, but we here merely refer to their motion generally. It is now believed, from the best observations which have been made, that the comets move in exceedingly long oval orbits, by which means they are at one time very near to the Sun, and at other times at an immense distance from him; still, however, the same general resemblance to the orbits of planets is to be noted, and, in addition, that the elongation of the form of the cometary orbit is frequently excessive.

We shall hereafter have to show, that the four largest of the planets have moons, or satellites, revolving round them, of which our Moon, the Earth's satellite, is the one which attracts a larger share of our attention than any of the others. Now it is interesting to observe, that the Moon of itself describes an oval orbit round the Earth, in a similar manner as the Earth does round

the Sun. But here a singular effect results:—if the Earth were stationary, the Moon's orbit would be found, as in the case of the planets, to be an oval with respect to the Earth; as, however, the Earth revolves round the Sun, and, of course, carries the Moon with it, the real path of the latter becomes a very singular and complicated curve,—it is a zig-zag circle round the Sun, with several indentations and as many protuberances.

Thus then do we form some general idea of the manner in which the planets are situated, with respect to one another and to the Sun. It will be useful to recapitulate a few points before we proceed further.

We have seen that there is a glorious luminary, the Sun, in the centre of a moving system; that there are eleven planets revolving round him in the following order, beginning from the nearest,—Mercury, Venus, Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus; that these planets describe paths which are not quite circular but oval, and that the Sun is in one focus of the ellipse or oval. The motions of the planets we have likewise found are not uniform, but that their velocities vary according to their distances from the Sun. These general details will qualify us to enter upon the consideration of all the planets individually, their dimensions, distances from the Sun, velocities of motion, influence upon one another, apparent size as seen from the earth, and many other points of interest to the admirers of the works of God. When that inquiry shall have been completed, we shall enter upon the consideration of those very beautiful and important results, which depend upon the rotation of the planets on their axes,—a species of motion to which we have not hitherto alluded.

We cannot better conclude this portion of our subject than by presenting the reader with the eloquent words of a pious and eminent divine, in connexion with the sublime subject which has thus far occupied us.

"The world in which we live, is a round ball of a determined magnitude, and occupies its own place in the firmament. But when we explore the unlimited tracts of that space which is everywhere around us, we meet with other balls of equal or superior magnitude, and from which our Earth would either be invisible, or appear as small as any of those twinkling stars which are seen on the canopy of heaven. Why then suppose that this little spot, little at least in the immensity which surrounds it, should be the exclusive abode of life and intelligence? What reason to think that those mightier globes which roll in other parts of creation, and which we have discovered to be worlds in magnitude, are not also worlds in use and in dignity? Why should we think that the great Architect of nature, supreme in wisdom, as He is in power, would call these stately mansions into existence and leave them unoccupied? When we cast our eye over the broad sea, and look at the country on the other side, we see nothing but the blue land stretching obscurely over the distant horizon. We are too far away to perceive the richness of its scenery, or to hear the sound of its population. Why not extend this principle to the still more distant parts of the universe? What though, from this remote point of observation, we can see nothing but the naked roundness of yon planetary orbs? Are we therefore to say, that they are so many vast and unpeopled solitudes; that desolation reigns in every part of the universe but ours; that the whole energy of the Divine

attributes is expended on one insignificant corner of these mighty works; and that to this Earth alone belongs the bloom of vegetation, or the blessedness of life, or the dignity of rational and immortal existence?

"But this is not all. We have something more than the mere magnitude of the planets to allege in favour of the idea that they are inhabited. We know that this Earth turns round upon itself; and we observe that all those celestial bodies which are accessible to such an observation, have the same movement. We know that the Earth performs a yearly revolution round the Sun; and we can detect, in all the planets which compose our system, a revolution of the same kind, and under the same circumstances. They have the same succession of day and night. They have the same agreeable vicissitude of the seasons. To them light and darkness succeed each other; and the gaiety of summer is followed by the dreariness of winter. To each of them the heavens present as varied and magnificent a spectacle; and this Earth, the encompassing of which would require the labour of years from one of its puny inhabitants, is but one of the lesser lights which sparkle in their firmament. To them, as well as to us, has God divided the light from the darkness, and he has called the light day, and the darkness he has called night. He has said, let there be lights in the firmanent of their heaven, to divide the day from the night; and let them be for signs, and for seasons, and for days, and for years; and let them be for lights in the firmament of heaven, to give light upon their earth; and it was so. And God has also made to them great lights. To all of them he has given the Sun to rule the day; and to many of them has he given moons to

rule the night. To them he has made the stars also. And God has set them in the firmament of heaven to give light upon their earth, and to rule over the day, and over the night, and to divide the light from the darkness; and God has seen that it was good.

"In all these greater arrangements of Divine wisdom, we can see that God has done the same things for the accommodation of the planets that he has done for the earth which we inhabit. And shall we say, that the resemblance stops here because we are not in a situation to observe it? Shall we say, that this scene of magnificence has been called into being merely for the amusement of a few astronomers? Shall we measure the counsels of heaven by the narrow impotence of the human faculties? or conceive that silence and solitude reign throughout the mighty empire of nature; that the greater part of creation is an empty parade; and that not a worshipper of the Divinity is to be found through the wide extent of yon vast and immeasurable regions?

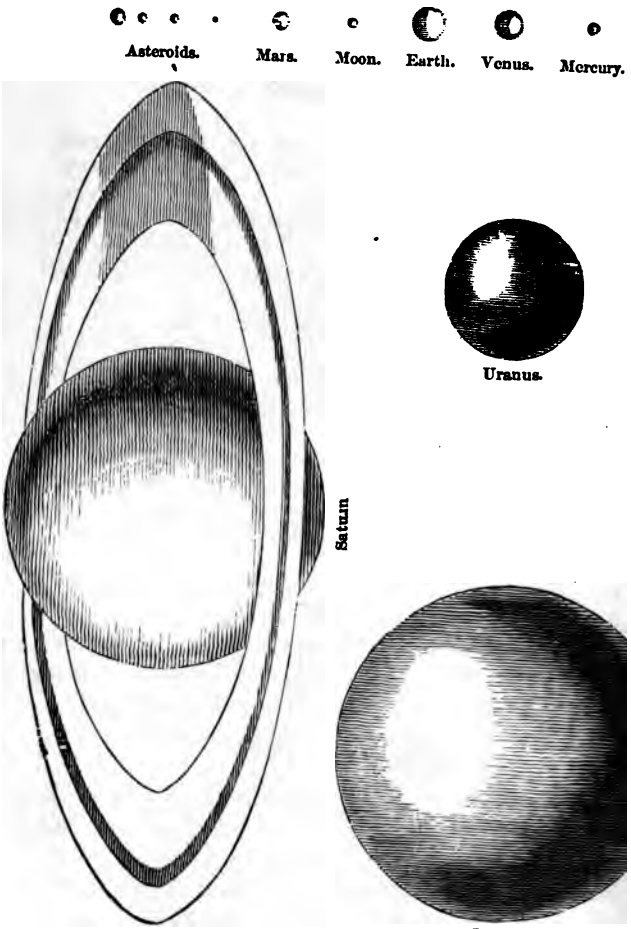
"It lends a delightful confirmation to the argument, when, from the growing perfection of our instruments, we can discover a new point of resemblance between our Earth and the other bodies of the planetary system. It is now ascertained, not merely that all of them have their day and night, and that all of them have their vicissitudes of seasons, and that some of them have their moons to rule their night, and alleviate the darkness of it; we can see of one that its surface rises into inequalities, that it swells into mountains and stretches into valleys; of another, that it is surrounded by an atmosphere which may support the respiration of animals; of a third, that clouds are formed and suspended over

it, which may minister to it all the bloom and luxuriance of vegetation; and of a fourth, that a white colour spreads over its northern regions, as its winter advances, and that, on the approach of summer, this whiteness is dissipated, giving room to suppose, that the element of water abounds in it, that it rises by evaporation into its atmosphere, that it freezes upon the application of cold, that it is precipitated in the form of snow, that it covers the ground with a fleecy mantle, which melts away from the heat of a more vertical sun; and that other worlds bear a resemblance to our own, in the same yearly round of beneficent and interesting changes.

"Who shall assign a limit to the discoveries of future ages? Who can prescribe to science her boundaries, or restrain the active and insatiable curiosity of man within the circle of his present acquirements? We may guess with plausibility what we cannot anticipate with confidence. The day may yet be coming, when our instruments of observation shall be inconceivably more powerful. They may ascertain still more decisive points of resemblance. They may resolve the same question by the evidence of sense, which is now so abundantly convincing by the evidence of analogy. They may lay open to us the unquestionable vestiges of art, and industry, and intelligence. We may see summer throwing its green mantle over these mighty tracts, and we may see them left naked and colourless after the flush of vegetation has disappeared. In the progress of years or of centuries, we may trace the hand of cultivation spreading a new aspect over some portion of a planetary surface. Perhaps some large city, the metropolis of a mighty empire, may expand into a visible spot by the powers of some future telescope.

Perhaps the glass of some observer, in a distant a
may enable him to construct the map of another wo
and to lay down the surface of it in all its minute
topical varieties. But there is no end of conjectu
and to the men of other times we leave the full
surance of what we can assert with the highest pro
bility, that yon planetary orbs are so many worlds, t
they teem with life, and that the mighty Being w
presides in high authority over this scene of grand
and astonishment, has there planted the worshippers
His glory."—CHALMERS, *Astronomical Discourses.*

Fig. 7.



COMPARATIVE SIZES OF THE PLANETS.

CHAPTER IV.

NOMENCLATURE AND DIMENSIONS OF THE PLANETS. THE SUN — DIMENSIONS OF, REAL AND APPARENT. MODES OF MEASUREMENT BY ANGLES. DEGREES, MINUTES, AND SECONDS. LUMINOUS AND HEATING EFFECTS OF THE SUN.

But yonder comes the powerful King of Day,
Rejoicing in the East. The lessening cloud,
The kindling azure, and the mountain's brow
Illumed with fluid gold, his near approach
Betoken glad. Lo! now, apparent all,
Aslant the dew-bright earth and coloured air,
He looks in boundless majesty abroad;
And sheds the shining day, that burnish'd plays
On rocks, and hills, and towers, and wandering streams,
High gleaming from afar.

[illegible] does Thomson, the philosophic poet of the *Seasons*, [illegible]k of the approach and vivifying influence of that [illegible]did body,—the Sun,—whose daily return brings [illegible] it so much that renders pleasure and benefit to [illegible].

[illegible]e have already given a general view of the relation [illegible]ing between the different heavenly bodies. The [illegible]pearances which are presented to the eye of an observer, an enumeration of the classes into which, for the sake of convenience, the heavenly bodies may be divided, and a short exposition of the mode in which

the theory of gravitation is brought to assist us in the comprehension of their motions, were the subjects which then occupied us. We proceed now to consider each of the planets separately, by which means we shall be able to collect the principal facts and circumstances connected with each planet, so far as that can be done without the aid of mathematics, which does not form a prominent feature in our plan.

Before proceeding to the consideration of the heavenly bodies separately, it will be convenient to consider the relation which exists between them all, as regards dimension. Fig. 7 represents the comparative sizes of the Moon and planets. By this we shall, of course, be understood to mean, that the twelve circles represented in p. 48, bear the same proportion one to another, as the diameters of the planets bear to one another, respectively. The Sun is so very much larger than any of the planets, that we could not introduce into our figure a circle which would indicate his comparative diameter. This will be rendered evident by the consideration that a circle showing correctly the comparative size of the Sun, must be one hundred and eleven times as large in diameter as the circle representing the Earth.

The diameter of the Earth, as we shall hereafter have to show more fully, is about 7920 miles. If now, for the sake of fixing our ideas, we call that quantity 1, then the diameters of the other bodies will be represented by the following numbers:—

☉ Sun	111·454
♃ Jupiter	10·860
♄ Saturn	9·987

♅	Uranus	4·332
⊕	Earth	1·000
♀	Venus	0·975
♂	Mars	0·517
☿	Mercury	0·398
☾	Moon	0·273
⚴	Pallas	0·265
⚵	Juno	0·180
⚳	Ceres	0·130
⚶	Vesta	0·030

The last four must be considered as approximations to the true proportions; as the diameters of those small planets have not yet been defined with so much precision as those of the other planets. In astronomical works, these heavenly bodies are frequently expressed by symbols appropriated to them. Before the name of each we have placed the symbol, which distinguishes it among astronomers.

The names of the heavenly bodies, before mentioned, are derived from the heathen gods, who also gave their names to such of the metals as were known to the ancients, and likewise to the days of the week.

The planets Uranus, Pallas, Juno, Ceres, and Vesta, were not known before the last sixty years. They have all been generally named from the relationship of one deity to the other; the moderns having called the planet discovered by Herschel Uranus, who, in the heathen mythology, was the father of Saturn, who was the parent of Jupiter, of whom Mars was the son. The Moon, called Luna, was said to be the daughter of Terra, the Earth. The characteristics of the planets were also indicated by the known qualities of the

deities whose names they respectively assumed. The Earth, being considered as the parent of all created nature, was designated from the goddess whom the ancients invoked to dispense all natural blessings. It formed the centre of their astronomical system, as we have already shown. The planet Mercury, seldom seen, and then but for a short time, resembled "the fleet messenger of the gods." Venus, the most beautiful of all the planets, was the type of the charming goddess of this name. Mars, with its red appearance, showed the wrathful countenance of the god of war. Jupiter, the largest of the planets, resembled the mighty "father of gods and men," while the dim-looking Saturn had its counter-part in the figure of the aged and morose progenitor of Jove.

The metals, and the days of the week, which correspond respectively to the Sun, Moon, and five planets, may be seen in the subjoined table.

Sun	Gold	Sunday.
Moon	Silver	Monday.
Mars	Iron	Tuesday.
Mercury	Quicksilver	Wednesday.
Jupiter	Tin	Thursday.
Venus	Copper	Friday.
Saturn	Lead	Saturday.

We need not seek to account for the connexion of gold with the Sun, nor of silver with the Moon, when the poets of all ages and nations have celebrated "the golden sun," and "the silvery light of the moon." From iron the god of war formed the weapons of destruction; while the nimble Mercury, that slippery, light-fingered fellow, the patron of roguery throughout the ancient world, was well identified with quicksilver.

The metal tin seems to have been assigned to Jupiter, from the circumstance that the Corybantes, the priests of Cybele, who tended the infancy of Jupiter in Crete, used to drown his cries by the clashing of their tin cymbals. Copper is connected with the name of Venus, who was the tutelar deity of the island of Cyprus. This place, where Venus was born, formerly supplied the world with copper from its mines, and honoured Venus above all deities. Lead may have been set down as the type of Saturn, in consequence of the dull, lead-like appearance of that planet.

The days of the week were respectively connected with each planet, as each planet was said, according to the old astrological rules, to be in the ascendant for the particular day.

We need bring no arguments to show that we are justified in selecting the sun as the first object of our attention:—both from the influence which his superior dimensions enable him to exert on the other planets, and from the vast importance which attaches to him, as the source of light and heat to the other bodies of the solar system.

The Sun.

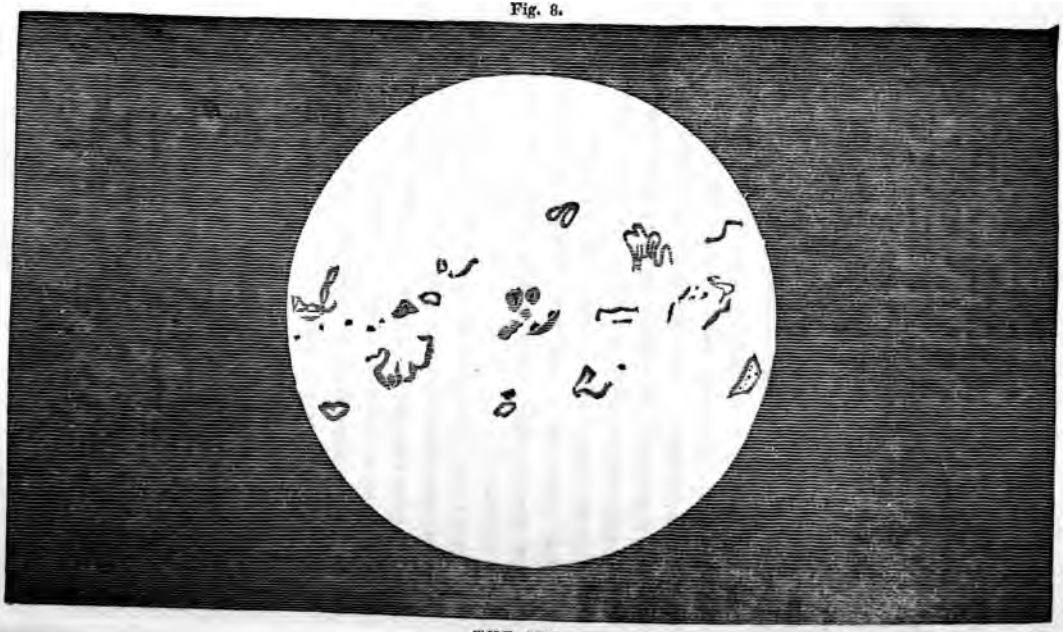
This magnificent globe is 883,210 miles in diameter, about 2,774,692 miles in circumference, and distant from the Earth about ninety-five millions of miles. It will be convenient to consider this luminary under three points of view:—1st. His apparent dimensions, as influenced by distance:—2nd. The phenomena presented by him as a source of light:—3rd. The heating effect of his rays.

1. The Sun has but a very small motion in the

heavens, which is due to the attraction of the different planets: nearly all the variations which appear in his dimensions arise from the motion of the planet on which the spectator is situated, and not from the motion of the Sun. But, although the motion of the Sun in an orbit is very small, never extending beyond the length of the solar diameter, yet he has another species of motion quite independent of any change of place; we mean a motion round his axis, which is completed in twenty-five days. The means by which this motion is made manifest, are the disappearance and re-appearance of certain dark or shaded spots, on his brilliant surface. These spots we shall have to allude to further on; but we may now state, that certain dark spots appear to travel, as it were, across the sun,—disappear at the western edge,—become lost for a time to the view,—re-appear at the opposite or eastern edge,—and then attain their former position. This can only occur on the supposition, that the Sun revolves on an axis; and the period of such revolution, as determined by these spots, after making allowance for the motion of the Earth, is, as we have stated, about twenty-five days. It is easy to produce familiar illustration of such a motion. Suppose that we have an orange, with a dark spot on one part of its surface: if we turn the orange round on its axis, that is, in the way that a top spins, we shall find that the dark spot will gradually reach one edge of the visible part of the orange,—pass round on the remote side,—and re-appear on the opposite edge from that at which it previously disappeared.

The apparent size of a body to a spectator depends on two circumstances:—First, the real size of the object;

Fig. 8.



THE SUN.

and, secondly, the distance at which it is placed from the observer. Now, as we may reasonably suppose that the Sun's dimensions are constant, any variation in his apparent size must be due to distance. It may now be asked by one who has not previously thought of these subjects, how we can describe in words, the size of which the Sun appears to us? If we say that he looks as large as an orange, no definite information is conveyed to the mind by such a statement; because, if an orange be held at a few inches distance from the eye, it will appear much larger than the Sun; whereas, if it be held at some yards distance, it will appear smaller than the Sun. It is obvious, therefore, that we must devise some other mode than comparisons of this sort, if we wish to convey to others an idea of the size of an object.

The mode which is adopted for this purpose, is to express the angle, which the diameter of a body *subtends*, or *is opposite to*. As we shall frequently have to speak of the word *angle*, it may be desirable to explain in this place what is meant by that term, and how angles are measured. Suppose that we have a stick, or any other object, which we wish to place upright, on one of its ends, on a table. We know that, unless it be quite upright, it will fall; and by the word *upright*, we mean that it inclines neither one way nor the other, Now it has been agreed that we shall call the position which the stick thus occupies with respect to the table, by the name of a right angle. Thus, (fig. 9,) if A C be the stick standing upright on the table C B, the opening or space included between the stick A C, and the table B C, is called a *right* angle. Suppose now that we lean the stick into the direction denoted by the dotted line

D C: then the opening or space included between the stick and the table will be smaller than before. When we incline the covers of a book towards each other, in the act of closing the book, we produce a similar effect to that which we have just noticed;—that is, we make two lines, or two surfaces (as the case may be,) close towards each other, as if one were about to lie on the other. This effect, then, is expressed, by saying that the angle D C B is smaller than the angle A C B. (We always place the letter attached to the point of junction of the two lines, between the two letters indicating the other ends of those lines.) If the stick were still more

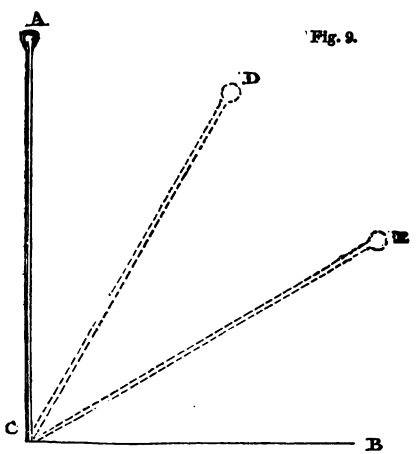


Fig. 9.

inclined, so as to occupy the position E C, then it would appear to approach still nearer to the table; the space included between them would be smaller; and we should say that the angle E C B is smaller than either of the former angles. It is observable that, in this way

of considering the subject, the length of the stick, and the length of the table, have nothing whatever to do with the size of the angle; this is a constant rule whenever the size of angles is spoken of.

As we thus acquire the means of distinguishing a large angle from a small one, we must now inquire what are the means by which two angles admit of being compared with each other. The opening which we have called a right angle, is supposed to be divided into ninety equal parts, called degrees. If the stick were so much inclined, that the opening between it and the table were only one degree, the stick would be almost lying down on the table. If the angle were two degrees, the stick would be a little more raised, and so on, until it became quite upright, when it would form a right angle, or an angle of ninety degrees, with the table. For further convenience, a degree is subdivided into sixty minutes, and a minute into sixty seconds. These divisions are known by the symbols ° ′ ″:—thus, 25° 48′ 50″, implies twenty-five degrees, forty-eight minutes, and fifty seconds.

We shall now find that this mode of proceeding furnishes us with a very convenient method of describing the apparent diameter of the Sun. If a line were drawn from the eye to the top of the Sun, and another line from the eye to the lower part of the Sun, those two lines would be very nearly parallel, or one would nearly lie upon the other. But still they would not do so exactly; and the small space between them would furnish us with an angle, to which we could give a value and a name. Now, it is found that two lines so situated, would form an angle of about half a degree: when, therefore, we speak of the diameter of a

planet subtending an angle of so many minutes, we mean, that if one line were drawn from one edge, and another from the opposite edge of the object, to the eye, those two lines would form with each other an angle of such dimensions.

The Sun is nearer to the Earth at one part of the year than he is at another, as the Earth's orbit is oval, not circular; and the Sun is in the focus of that ellipse, or oval. When, therefore, the Earth is at that portion of her orbit which is nearest to the Sun, which takes place in our winter, the Sun must obviously appear larger to a spectator on the Earth's surface, than in the summer, when the Earth is further from the Sun: accordingly, it is found that in the middle of Winter, the Sun's diameter is about thirty-two and a half minutes, and at midsummer about thirty-one and a half minutes of a degree. From the apparent diameters of the Sun and planets, their real diameters are easily calculated, when the distances of these bodies are once known.

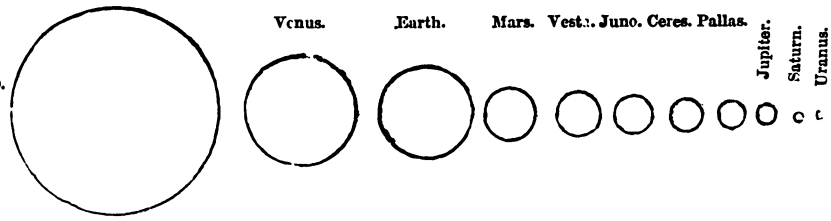
The apparent dimensions of the Sun, as seen from the other planets, may be thus conveniently expressed by means of the angle, as before described. We shall, however, find it more satisfactory to present in a diagram, (fig. 10,) the comparative dimensions of the Sun, as seen from the different planets:—for instance, if a circle of half an inch in diameter be made, as in the figure below, to represent the Sun as seen from the Earth, then the diameter and apparent size of the Sun, as seen from each of the ten planets, will be as laid down in the diagram.

2. *Luminous effects of the Sun.* What light is we know not! Its cheering, grateful influence, we al feel

From

Mercury. Venus. Earth. Mars. Vesta. Juno. Ceres. Pallas. Jupiter. Saturn. Uranus.

Fig. 10.



COMPARATIVE DIMENSIONS OF THE SUN, AS SEEN FROM THE DIFFERENT PLANETS.

and acknowledge; but we do not know of what, nor how, it is made. From the moment that the Creator made the Sun, "to rule the day," up to the present moment, this Sun has continued to shed a flood of light upon all around: and yet the store is not exhausted; nor is it diminished, so far at least as we can tell.

The ancients believed that the Sun was a globe of fire, which constantly darted its beams upon the Earth; but modern science has elicited circumstances, which seem to show that such is not the case. If the Sun be viewed through a powerful telescope, with coloured glasses interposed to prevent the intense light and heat of the Sun from hurting the eye, it will be found that there are numerous dark spots of various forms and dimensions. Some of them are perfectly black, while others have a shaded or partially-enlightened appearance. These spots, which were first made known to the world by Galileo, about two hundred and forty years ago, are subject to much fluctuation: sometimes they appear to expand and enlarge in their dimensions; at other times they seem to contract and become less perceptible. Sometimes they divide into a greater number, while at other times two or more appear to coalesce. Some of these spots have been supposed to be of the immense magnitude of forty-five thousand miles in diameter; and they have been observed to close up entirely in the space of six weeks; which renders a velocity of a thousand miles per day necessary for the approaching borders of any such spot.

Those parts of the Sun's surface which are not occupied by these spots, are still far from uniform in their appearance; they have in many places a mottled

aspect, as if numerous pores, or small apertures, were present in the luminous surface. There are, again, other places, which are occupied with luminous vapours and lines brighter than the general surface, and which are called *faculæ;* while the dark spots mentioned before are termed *maculæ**.

From all these circumstances it has been conjectured that the substance or body of the Sun itself is really dark or non-luminous; but that he is surrounded with a luminous atmosphere; and that any diminution or removal of such atmosphere at any given point will occasion the dark appearance, which we call a macula. By some it has been supposed that the black spots are the summits of lofty mountains, which penetrate beyond the luminous atmosphere, and therefore present a dark appearance to the eye. To this it has been objected, that, if such were the case, the sides of the mountain would present a gradation of light, from the black spot at the summit, to the general brilliancy of the sun's surface; whereas, such is not found to be the case. The black spots are in many cases surrounded with *penumbræ*, or partially luminous portions, terminated by distinct and well-defined edges; thereby presenting no appearance of gradation of luminosity.

All these circumstances are considered to lead, more or less directly, to the conclusion, that the Sun owes its brilliantly luminous appearance to an atmosphere which surrounds it; and this supposition is further supported by a very remarkable fact, which the progress of optical science has revealed during the present century. There is often used in experiments in Optics, a three-

* Maculæ is the Latin for *dark spots*; faculæ, *little torches.*

cornered piece of glass, called a prism, which is oblong, and which if viewed endwise has a triangular form. When the Sun's rays pass through a piece of glass, or other transparent body, of this form, the beam of light is spread out into an oblong form, and is variously coloured,—being red at one end and violet at the other: —the space between being occupied by orange, yellow, green, blue, and indigo. These are the appearances presented under general circumstances; but if this oblong coloured space (which is called the solar *spectrum**) be carefully viewed with the aid of a telescope, it is found to be crossed by a large number of fine dark lines,—as many, indeed, as six hundred in the whole.

Now it is supposed that this is owing to the absorption, on the part of the Sun's atmosphere, of some of the coloured rays of light, whereby a black line is given out at those parts of the spectrum which, had the rays in question not been absorbed, would have uniformly contained coloured rays.

Sir William Herschel, who was for many years the Astronomer Royal, supposed that there was an elastic atmosphere surrounding the Sun, composed of a cloudy, or partially visible, stratum of air; and that above this atmosphere was a luminous or light-giving atmosphere. When, from any cause, a portion of the latter atmosphere was removed, a dimly reflected light would be seen on the surface of the cloudy stratum, and thus the faint light, or penumbra, is perceived. At any rate, the central part of the Sun's disk† appears, notwithstanding

* A Latin term implying *an appearance.*

† By the term *disk* is meant the *face* of the Sun or Moon, as seeming perfectly flat; the diameter of which is considered to be divided into twelve parts, called *digits.*

the spots and irregular appearances, to be the most luminous. It must, however, be acknowledged that in this, as well as in many other branches of science, we know but little of the real nature of the cause, whose effects we study. Why it is that the Sun differs from almost all other bodies of which we are cognizant in nature, in constantly giving out light, without, so far as we know, receiving any light from any other source, is to us a mystery; and cannot fail to excite our admiration, —dependent as we are, for so much that is beneficial to us, on that

> . . . . . prime cheerer, Light!
> Of all material beings first, and best!
> Efflux divine! Nature's resplendent robe!
> Without whose vesting beauty all were wrapt
> In unessential gloom; and thou, O Sun!
> Soul of surrounding worlds! in whom best seen
> Shines out thy Maker! may I sing of thee?

3. *Heating effects of the Sun.* That the Sun is the most prolific source of heat is manifested to us in the grand routine of natural operations. We may warm our apartments by kindling a fire:—we may dress our food by the application of heat, either to the food itself, or to the water in which it is immersed;—and important and indispensable are such processes:—but, if we compare them with the phenomena of the seasons, how humble and trifling do they appear! A fire will convey warmth to but a small space around it, and to but a small number of persons; but how sublime and vivifying is the effect which that seeming "globe of liquid fire," the Sun, produces on the earth! The millions, who inhabit our globe, look to the heating power of the Sun, as the source by which their vegetable productions

must arrive at that maturity which will fit them for the purposes of food. What is it which renders the lichens and mosses of the polar regions so different from the luxurious plants of the tropics? It is not the nature of the soil in which they grow; nor the amount of attention which they receive from man:—but it is the extent of the Sun's warmth which mainly constitutes the difference referred to. The traveller in tropical climes meets with luxuriant fruits in abundance; while the navigator of the Arctic Seas is seldom cheered, when he touches land, with the sight of vegetation. Many of our readers have probably read Captain Franklin's account of a journey across the northern part of America; when the only food of the party for a considerable period was *tripe de roche**, which, though disagreeable in taste, was the only vegetable production which met their view in the course of a toilsome journey.

But we need not go to such extreme cases to instance the value of the Sun's warmth. What constitutes the difference between our own summer and winter? What makes the orchard and flower-garden present so different an aspect in spring and summer to what they afford in winter? The Sun's heat is the cause: not that he is present at one season, and absent altogether at the other; but that he is with us longer, and under more favourable circumstances, in June than in December. This, however, will occupy our attention hereafter:—we will

* A lichen, which grows chiefly on Alpine rocks, and exposed situations. The Canadian hunters are said to be often forced to subsist upon this vegetable, the leaves of which grow flat upon the rocks; hence it has been called by the natives *rock-tripe*.

therefore proceed to make a few remarks on the supposed nature of the Sun's heat.

The light which emanates from the Sun is accompanied by heat in its passage to the Earth and to the other bodies of the solar system; and it is extremely probable from recent inquiries, that light and heat are not the same bodies or agencies, or whatever we may call them. We just now spoke of the passage of light through a glass prism; but we must now consider that same light as being accompanied by heat. It is found that there is more heat at that end of the spectrum which contains the red rays, than at the other end; and it has even been proved that considerable heat exists beyond the limit of the coloured rays; that is, heating rays are found where there are no luminous rays whatever:—this is one of the circumstances which have given rise to the opinion, that the heating or calorific rays of the Sun are distinct from the luminous rays. The investigation of this circumstance was first set on foot by Sir William Herschel, who, while viewing the Sun's spots through a telescope, protected his eyes by coloured glasses, and found that more heat reached his eye when some colours were employed than with others; and that some of the glasses were cracked by the influence of the heat which they absorbed more readily than those of other colours,—the difference depending on colour. Another reason why solar heat and light are thought to be distinct is, that light has been filtered,—so to speak,—and a brilliant focus of light presented, so devoid of heat, as to be incapable of affecting the most delicate thermometer.

The intense character of the heat evolved by the Sun may be sufficiently shown by the employment of a com-

mon burning glass; the action of which is nothing more than this:—all the rays, both of light and heat, which fall on the surface of a lens, are brought into one narrow bundle, by what is called the refracting power of the glass. If, for instance, the glass be one inch in diameter, and we find the focus, which is a little bright spot or image of the Sun formed at a certain distance behind the glass, to be one-tenth of an inch in diameter, then will the light and heat be concentrated one hundred times, that is, the effects of a certain quantity of light and heat are assembled into a space only one hundredth part of the former space:—from this statement, however, some slight deduction will have to be made, on account of some of the rays being reflected from, and others absorbed by, the glass.

The substance of the Sun is considered to be of a weight and density corresponding to that of water; but, nevertheless, the extent of its bulk is such, that if the weight and density of the whole Earth be regarded as 1, the Sun's weight and density may be set down as 333,000.

Such are the general characteristics of the solar globe. Many other effects, produced by its means, we shall treat of in the proper place. It may be sufficient now to observe, that the action of the Sun's light and heat is the direct source of most of the processes which go on upon the Earth, whether relating to the atmosphere or to the vegetable and animal kingdoms.

CHAPTER V.

MERCURY. THE TERM PLANET DEFINED. PRIMARY AND SECONDARY, &c. MOTIONS OF. LUMINOSITY. PHASES. TRANSITS. CONJUNCTION AND OPPOSITION OF PLANETS. —VENUS. MOTIONS OF. PHASES. MORNING AND EVENING STAR. PARALLAX.

Mercury.

We now proceed to the consideration of the bodies which revolve round the Sun, and shall treat of them in the order of their distances, the nearest first.

We should remark, before proceeding further, that the word *planet* signifies a *wanderer;* an appellation given to those heavenly bodies, which seemed to move in circles in the heavens. Hence this distinction may refer both to the planets usually so called, and to their moons; the former of which are styled *primary*, the latter *secondary*, planets. Again, the primary planets are distinguished into *interior* or *inferior;* and *exterior* or *superior:*—the first pair of terms pertaining to the two planets whose orbits are between the Sun and the orbit of the Earth; the second pair referring to the planets more distant from the Sun than the Earth.

The planet nearest to the Sun, as far as we know for certain, is one,

> . . . . . whose disk
> Can scarce be caught by philosophic eye,
> Lost in the near effulgence of his blaze.

This is Mercury, which is somewhat more than thirty-six millions of miles distant from the Sun, and is

about three thousand one hundred and twenty-three miles in diameter. He revolves on his axis in about twenty-four hours five and a half minutes, being a little more than the time occupied by the Earth in revolving on her axis. He moves round the Sun in an elliptical orbit, (as we said do all the other planets,) and when we speak of the distance between him and the Sun, it must be understood that we refer to the mean distance. The time which he takes to travel round the Sun is almost eighty-eight days; a period which constitutes his year: for we must bear in mind, as will be hereafter more particularly shown, that our year is nothing more than the length of time which the Earth occupies in going once round the Sun. Hence, when we speak of a year as connected with the motion of Mercury, we must remember that his year is different from ours,—the latter being rather more than four times as long as the former.

As he revolves round his orbit of seventy-two millions of miles in diameter in about eighty-eight days, he has a velocity of motion of about one hundred thousand miles an hour; a rate of which we can form some conception by considering that one hundred thousand miles is about four times the circumference of the earth.

As Mercury is so much nearer the Sun than the Earth, it follows that the amount of light and heat received by this planet is much greater than that received by the Earth; and it has been estimated that it is about seven times greater. Another effect of the comparative proximity of Mercury is, that he never appears so far removed from the Sun as the other planets. At no time is he more than 30° distant from the Sun; that is, if at any time we draw a line

from the Earth to the Sun, and another from the Earth to Mercury, those two lines will never form a larger angle than 30°. It is, in part, for this reason that we do not usually speak of Mercury as a morning or an evening star; he never rises much before the Sun, nor does he set much after the Sun: and, in the next place, owing to the proximity of the Sun, by means of which the rays of this planet are, as it were, drowned, we seldom see him at any time. Not but that, in very clear weather, this planet may be seen just before sun-rise in the morning, or just after sun-set in the evening, when it appears a good way off from the Sun. His appearance is brighter than that of Venus, and has a light blue tint about it. He subtends an angle of from 5″ to 12″ of a degree, according to his position in respect of the Earth.

There is a circumstance which satisfactorily proves that Mercury does not shine by virtue of any light of his own, but merely by light reflected from the Sun. This circumstance, which also applies to some of the other planets, is the existence of phases*, similar to those which are periodically observed in our moon. When Mercury appears at his greatest distance or elongation from the Sun, his illuminated surface has nearly the form of a half circle, more or less, according to the position of the Earth. But when he is passing round on the opposite side of the Sun to that at which the Earth is situated, the illuminated portion becomes more than a semicircle, and assumes that form which is called *gibbous;* which phase may be represented by placing a semicircle and a semioval with their flat

* This is a word from the Greek, and signifies *appearances.*

edges in contact. When Mercury is at his greatest distance from the Earth, the Sun is then between them, and shuts out the view of Mercury altogether, so that the whole of the illuminated disk of Mercury can never be seen from the Earth; but when he emerges on the other side of the Sun, he becomes again visible, and his illuminated surface approaches more and more to the form of a semicircle, as he travels on to the position in which he forms a right angle with the Sun and the Earth. As he proceeds in his orbit, he approaches nearer to the Earth, and his semicircular phase becomes diminished to a crescent, which attains its smallest dimensions, when Mercury is either exactly over, or exactly under the Sun; in which position only a few of the Sun's rays, reflected from the surface of Mercury, can reach the Earth, and even those few are rendered almost imperceptible by the superior flood of light, which proceeds directly from the Sun to the Earth. These observations apply likewise to the planet Venus.

It is by such evidence as this that we know that a planet does not appear luminous by any inherent light of its own, but that we see it, in consequence of its reflecting the solar light to the Earth. There is every reason to believe that the Earth reflects light from its surface, just as we have described with respect to Mercury; and that if there be inhabitants in any of the other planets, they see the Earth under the various forms of crescent, semicircular, and gibbous. To this conclusion we arrive, both by analogy, and by certain appearances of the Moon during a solar eclipse, to which we shall hereafter refer more particularly.

A line drawn from the Earth to the Sun is said to

be in the plane of the ecliptic. The ecliptic may be imagined to be a large oval flat surface, which passes through the Sun, and round the edge of which the Earth moves in the space of a year. Now if we suppose a similar, but smaller, oval surface passing through the Sun, and that Mercury passes round the edge of that oval in his year of eighty-eight days, it may be asked whether these two oval surfaces coincide, or whether one slopes with respect to the other? We have to reply that they do not coincide; but that although both of them pass through the Sun, they are inclined the one to the other. It will perhaps be desirable here to state that each planet may be conceived to have an oval plane belonging to itself, round the edge of which it passes in the course of its year; and further, that no two of these planes exactly coincide, all of them being inclined one to another. Now the mode of expressing the amount of the inclination, or obliquity of two such planes, is by the angle included between them. Two such planes are said to cut each other in an imaginary line passing through the Sun, which line therefore may be considered as a kind of hinge, connecting the two planes; and the angle at which these planes are inclined to each other, is measured with reference to that line.

It will now be understood what is meant when we say that the plane of the orbit of Mercury is inclined at an angle of about seven degrees to the plane of the ecliptic, the latter term being always reserved for the plane of the Earth's orbit. If the plane of the orbit of Mercury coincided with the ecliptic, it would follow that Mercury, when at its shortest distance from the Earth, would be exactly between the centre of the Sun

and the centre of the Earth; and that we should therefore see him as a black spot on the central part of the Sun, which circumstance was first observed by Gassendi in the year 1631. As, however, the planes of the two orbits do not coincide, and yet the planet Mercury is occasionally seen as a black spot on the Sun's disk, the determination of the circumstance, whether or not Mercury will appear on the face of the Sun, depends on the position of the line, which joins the two planes. If Mercury happen to be at his nearest point to the Earth, when he reaches that line, then we shall see him cross the centre of the Sun's disk, in which case the line connecting the two planes will pass through the centres of the Earth, Mercury, and the Sun. But if that line be in any other direction, when Mercury gets between the Earth and the Sun, then he will be either a little above or a little below the centre of the Sun, or more probably, exterior to the disk of the Sun altogether.

From these circumstances it follows that Mercury may revolve many times round the Sun, without getting exactly on the line joining the Earth and the Sun. When, however, such an occurrence does take place, it is called a transit* of the planet. At such a time Mercury appears as a small round black spot, because his illuminated surface is directed wholly away from the Earth. He crosses the Sun's disk from east to west, in consequence of his motion from west by south to east. Such a transit as this occurred about the middle of the day on May 5th, 1832. These transits of the planets show that they are opaque bodies, having no light of their own.

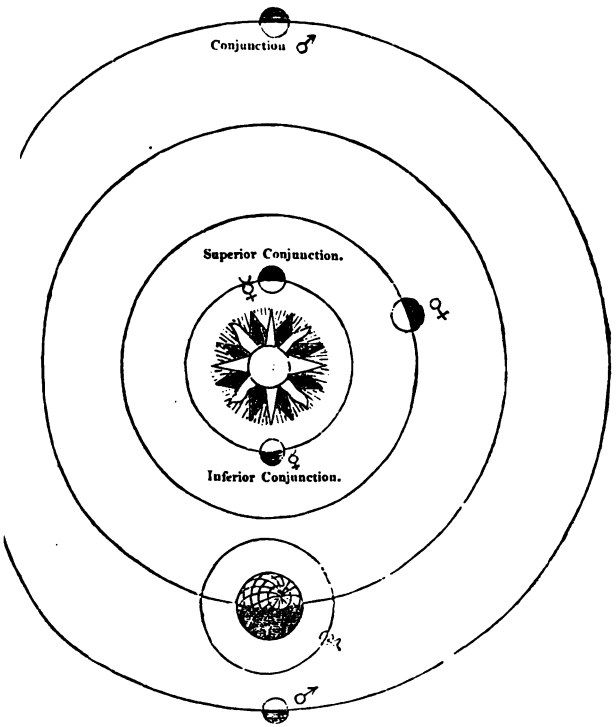
* From the Latin *transitus, a passing over.*

We must now explain two terms which will be frequently used in our future details; viz., *conjunction* and *opposition*. If we suppose a planet to be exactly between the Earth and the Sun, that planet is said to be in *inferior* conjunction with the Sun: and if the Sun be exactly between this planet and the Earth, the planet is said to be in *superior* conjunction with the Sun; the words *inferior* and *superior* being considered with reference to the smaller or greater distance of the planet from the Earth. This, however, is not all. If the planet be either a little above, or a little below the line which joins the centres of the Earth and the Sun, it is still said to be in conjunction. We shall therefore include all the cases, if we say that a planet will be in inferior conjunction with the Sun, when such planet is the nearer of the two to the Earth; but when the Sun is the nearer of the two, the planet will be in superior conjunction.

The term *opposition* is applied to two planets, or heavenly bodies, which are so situated that one particular plane, passing through both their centres, will also pass through the centre of the Earth, the Earth being between the other two bodies. This condition can never occur with respect to the planets Mercury and Venus, because, their orbits being smaller than that of the Earth, the Earth can never get between them and the Sun, as may be inferred by inspecting the opposite diagram.

The conjunction of one planet with another, or with the Sun, is in most cases a favourable opportunity for distinguishing that planet in the heavens, as we are thus furnished with a clue for detecting its position. The conjunctions and oppositions, as also the risings

Fig. 11.



ASPECTS OF THE PLANETS.

and settings of the planets, with their precise situations in the heavens, at certain given times, are set down in a species of almanac, devoted to the furnishing of this information, *day by day*, whence it is called an *Ephemeris*. This planet, as to density of matter, is deemed to be nine times that of water, or double the density of the matter of the Earth.

It is sometimes desirable to know when a planet is towards the south, for the convenience of recognising it; but such information is of less value in the case of Mercury than of any other planet, as the proximity of Mercury to the Sun renders it seldom visible. Its time of crossing the meridian, or attaining its southern or most elevated position, varies from about a quarter past ten to three-quarters past one in the day.

VENUS.

> With purest ray
> Sweet Venus shines; and from her genial rise,
> When day-light sickens, till it spring afresh,
> Unrivalled reigns, the fairest lamp of Night.

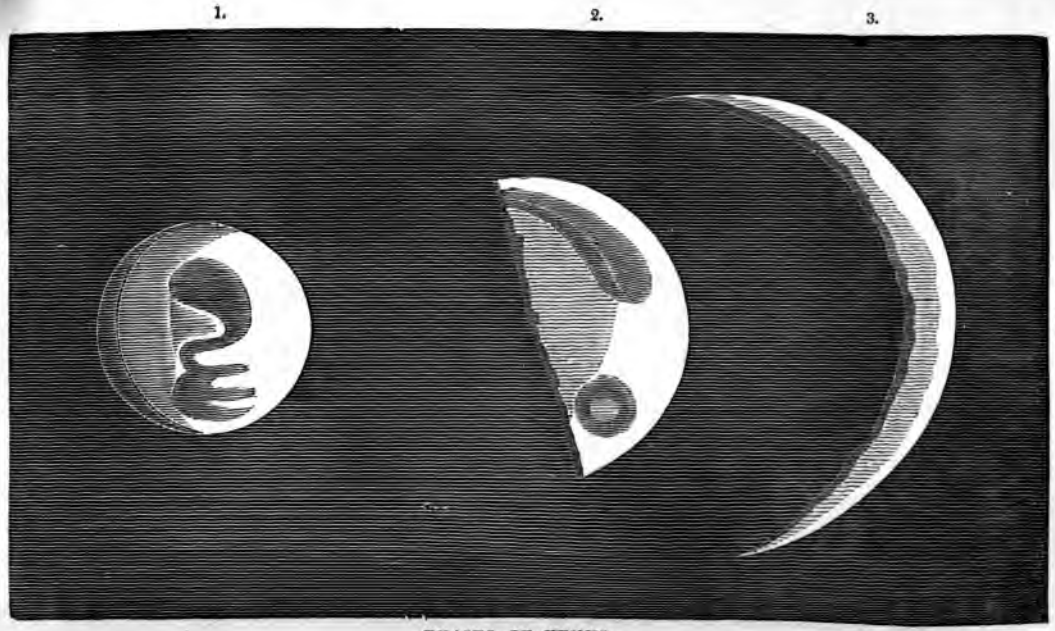
We need not wonder that the poet thus hails the appearance of an object, which attracts so large a share of admiration as the planet Venus, which glitters like a gem in the dark firmament, when the Sun is lighting other parts of the Earth, and which thereby helps to break the gloom which attends upon the sable night.

> Fairest of stars, last in the train of Night,
> If better thou belong not to the dawn,
> Sure pledge of day, that crown'st the smiling morn
> With thy bright circlet.
>
> MILTON'S *Paradise Lost*, b. v.

No other planet shines with so great clearness and brilliancy upon the Earth as Venus,—a circumstance due to her size, but more particularly to her nearness to the Earth. In dimensions Venus approaches much more nearly to those of the Earth than any other planet, her diameter being about seven thousand eight hundred miles; so that if we divide the earth's diameter into sixty-six equal parts, the diameter of Venus will contain sixty-five of those parts.

Venus revolves round the Sun in an orbit, which is inclined to the Earth's orbit, or ecliptic, the inclination, however, not being so great as in the case of the orbit of Mercury, this latter inclining, as we said, about seven degrees, while the former inclines less than three and a half degrees. Her mean, or medium distance, from the Sun is about sixty-nine millions of miles, nearly twice as great as that of Mercury. This mean distance gives for the circumference of her orbit about four hundred and thirty-three millions of miles, a distance which she travels over in about two hundred and twenty-five days; so that eight of her years are about equal to five of ours. The velocity with which she moves in her orbit is about seventy-five thousand miles an hour, about three-fourths of the velocity of Mercury. Besides the motion in her orbit, she has a rotation on her own axis, which occupies about twenty-three hours and twenty minutes. This rotation is determined by carefully watching the permanent spots on the body of the planet.

The observations which we made about phases, when speaking of Mercury, apply with much more force when referred to Venus, for two reasons;—first, her illuminated surface is larger than that of Mercury,—



PHASES OF VENUS.

Fig. 12.

and secondly, her distance from the Earth is subject to much greater variation than that of Mercury. At her nearest point to the Earth, she is probably about twenty-six millions of miles distant; but her greatest distance from the Earth is one hundred and sixty-four millions of miles. It is obvious, therefore, that the splendour of her light, and her apparent size, must suffer considerable modifications, as well from her varying distance, as from the phases which she exhibits. This is well illustrated in the different figures or phases of this planet, as given in fig. 12. The first phase, which is the *gibbous*, shows Venus, just after having passed from superior conjunction, and when at almost its greatest distance from the Earth; it not being seen when in a line with, or too close to, the Sun. The second phase corresponds to our *half-moon*, and is the aspect of Venus when forming a right angle with the Sun and the Earth; it is then at its greatest elongation. The third phase, or *crescent*, is observed just before and after the planet's inferior conjunction, and when at about its nearest distance to the Earth. Hence it has been noticed, as shown in the figure opposite, that the apparent size of Venus is indicated as greatest by the *crescent* form, and that her light is then most brilliant and abundant; and that her apparent size is least when in the *gibbous* state, and her light proportionably diminished:—all depending upon her distance from the Earth. When Venus gets near to the Earth she appears upwards of thirty times larger than when farthest off; and her light about this time is so intense as to project a real shadow upon a white ground, such as clean writing-paper. She may even be seen in the day-time, near, and soon after her greatest elongation.

The phases of Venus were first pointed out by Galileo; this being one of his earliest discoveries with the telescope.

Venus, like Mercury, being an inferior planet, cannot, of course, be at any time in opposition to the Sun: indeed, she never recedes further from him than 47°, which is her greatest elongation, or the angle which would be formed by two lines drawn to the Earth, one from the Sun and the other from the planet. The orbit of Venus being exterior to that of Mercury, the greatest elongation of Venus, specified by the angle mentioned above, is necessarily greater than that of Mercury; to which circumstance it is owing that Venus is sometimes visible above the horizon for more than three hours before the Sun rises, and upon other occasions for as long a time after the Sun has set:—in the former case she is to the west of the Sun, and is called a *morning star*, and in the latter she is to the east and is designated an *evening star**. The elongation of a planet refers, then, to that position in which the planet is seen at its greatest distance from the Sun; at which time the planet appears, as we just said, in the shape of a half-moon:—these phases, however, cannot be perceived without the aid of a telescope.

The surface of this planet is found to exhibit spots, similar to those of which we shall hereafter have to speak in the case of the Moon. By these spots not only the rotation of the planet on her axis has been deter-

* This is the planet which, rising before the Sun, the old poets termed Phosphorus and Lucifer; both words meaning *light-bearer*. When setting after the Sun, in the evening, they termed it Hesperus or Vesper; which terms have relation to the *evening*.

mined, but the inclination of that axis to the axis of her orbit has been found to be as much as 75°. The inclination of the Earth's axis to the ecliptic, or path of the Earth round the Sun, is about 66½°; and this inclination causes the diversity of seasons. How much greater then must be the diversity of seasons on the face of the planet Venus, than on the Earth! Some parts of her surface may enjoy the four seasons twice in the year. The light and heat which she receives from the Sun, is probably about twice as great as that received by the Earth.

We have now to speak of a train of observations, which were productive of important consequences, and in which the planet Venus rendered great service,—we mean the correct calculation of the Sun's parallax; and from that, his distance from the Earth, by means of a transit of Venus across his disk. We have stated that Mercury occasionally crosses the Sun's disk, as viewed from the Earth; and it may reasonably be expected that Venus, being, like Mercury, an inferior planet, would likewise cross the Sun's disk at certain times. Such is the case,—as was first observed by Horrox, a student of Cambridge, in the year 1639; but the transits of Venus occur with much less frequency than those of Mercury. The former happening alternately at intervals of eight and a hundred and thirteen years, nearly. The most celebrated of these transits occurred respectively in the years 1761 and 1769;—celebrated, because many of the European governments sent out scientific expeditions, in order that this phenomenon might be observed at different parts of the Earth, with the greatest accuracy, and under the most favourable circumstances. At the time of the transit, Venus must,

of course, be at its nearest position in respect of the Earth, and its apparent diameter will be of the largest extent, which is 61″, or five times that of Mercury. The mean apparent diameter of Venus is about 17″.

The final object, which was more particularly held in view in making these observations was, to determine with greater precision than had been previously done, the distance of the Earth from the Sun; in order that the true magnitude and extent of the whole solar system might be from thence determined. The manner in which this was accomplished does not admit of a full explanation, without entering into more intricate details than are suitable to this work. We must, however, briefly explain the nature of parallax;—as it was through the medium of this phenomenon that the transit of Venus was rendered available for the object in view; and as the question of parallax is one of the fundamental principles, called into use, in our endeavours to appreciate the distances of the heavenly bodies.

The first step to the accomplishment of the main purpose was to ascertain the parallax of Venus; as a medium point, whereby the solar parallax might be more precisely obtained.

The term *parallax* signifies *a change* produced *by passing by*. Familiarly speaking, we have parallax constantly taking place; when an object is seen in relation to any other spot, owing to our changing our position. A parallax of the steeple in the following cut takes place, when the observer changes his station of view. When he is in the West, he sees the form of the steeple thrown towards the East: coming up to the foreground he sees it to the North; and, advancing on to the East, he sees the steeple Westward.

Fig. 13.

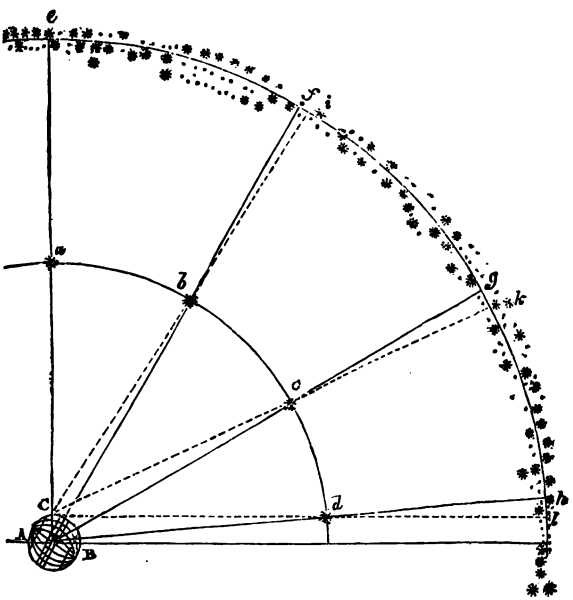
Now, astronomically speaking, parallax is defined to be the angular distance of any heavenly body between its *true* and *apparent* place; the former being its place as it would be seen from the centre of the Earth, and the latter as it actually appears from any part of the Earth's surface. As a heavenly body can only be viewed from the Earth's surface, its position is referred to, in calculations, by a necessary allowance, as seen from the centre of the Earth, which process is termed *the reduction for the centre.*

In the succeeding diagram this principle is illustrated; as also the following results: that a heavenly body, seen in the zenith, or point in the heavens just over our heads, can have no parallax, because it is seen in a straight line with the centre of the Earth; that the horizontal parallax is greatest of all; and that the parallactic angle diminishes in proportion as the celestial body reaches the zenith.

Let A B be the Earth, and C a part of the Earth's surface, from whence the heavenly bodies *a b c d* are viewed in the direction of the dotted lines; by which *a b c d* appear on the heavens at *e i k l*, respectively. Now if the Earth were transparent, a spectator placed at its centre, would see the four heavenly bodies *a b c d* at *e f g h*, respectively; which would be the *true* places. Hence the *true* place of a heavenly body is somewhat higher than its *apparent* place, excepting as was said before at the zenith; where the true and apparent places of objects coincide. The angle formed by the two lines at *b*, *c*, or *d*, is the parallactic angle.

Such then is the nature of parallax: and it will be seen that the horizontal parallax is nothing more than the angular dimensions of half the Earth's diameter, as seen from the planet. With such a planet as Venus, which approaches comparatively near to the Earth, the effect of parallax is considerable; but with respect to the Sun itself, such is not the case; for the Sun, being at the average distance of ninety-five millions of miles from the Earth, the semi-diameter of the Earth must appear exceedingly small, when viewed from such a distance. This small quantity is, however, made more sensible by the transit of Venus over the face of the Sun; for an observer, situated eastward on the Earth's surface, sees Venus begin to pass over the disk of the Sun somewhat earlier than another observer, situated more to the west; and the chord described by the planet upon the solar disk will appear somewhat greater or smaller, according to the situation of the observers upon the Earth's surface. Hence the difference in the position of view gives a difference of time, taken up by Venus in her passage over the Sun, which furnishes, by

Fig. 14.



a process which we cannot detail here, an angular quantity, which, after the necessary corrections for the Earth's rotation, and the station of the observers, leads to the horizontal parallax of the Sun; and this is about 8·6 seconds.

In what way this parallax enables the astronomer to determine the distance of a planet, we may briefly explain by referring to one of the properties of the triangle. In the annexed figure, the angle at *d* represents the horizontal parallax of the celestial body *d*. This angle is a known quantity, and so is likewise the line from c to the centre of the Earth, which is half the Earth's diameter, and is about three thousand nine hundred and sixty miles. Now, if in any right-angled triangle, such as this is, we know the length of the base, and also the value of the angle opposite to it, we can deduce the length of the sides; by which means we obtain the distance of the planet *d* from the centre of the Earth.

Some years ago M. Schröeter, an eminent astronomer of Lelienthal, made a continued series of observations on the planet Venus, for a period of ten years; and his labours led to many remarkable discoveries. He found himself able to determine that there were mountains on the surface of that planet, analogous to those on the surface of the Earth; and that the actual height of some of them amounted to 22·05 miles. Three of them he found to be of the respective heights of 18·97, 11·44, and 10·84 miles. He also perceived evident indications that Venus was surrounded by an atmosphere, which is said to be fifty miles in length.

This planet seems to be composed of matter, which is somewhat denser than the matter of the Earth.

CHAPTER VI.

THE EARTH. ITS FORM. CENTRIFUGAL FORCE. POLES. PERIHELION AND APHELION. THE YEAR—TROPICAL AND SIDEREAL. DIURNAL REVOLUTION. SIZE AND DENSITY OF THE EARTH. THE MOON—GENERAL PHENOMENA OF. THE MONTH AS DETERMINED BY THE MOON. VIEW OF THE EARTH TO THE MOON. LUNAR DAYS AND SEASONS. LIBRATION. THE HARVEST MOON AND THE HUNTER'S MOON. NODES. DISK. PHASES OF THE MOON. ECLIPSES OF THE SUN AND MOON.

The Earth.

. . . . . What if the Sun
Be centre to the world, and other stars
By his attractive virtue and their own
Incited, dance about him various rounds?
Their wandering course now high, now low, then hid,
Progressive, retrograde, or standing still,
In six thou seest, and what if seventh to these
The planet Earth, so steadfast though she seem,
Insensibly three different motions* move?

MILTON'S *Par. Lost*, b. viii.

WE have now arrived at the third planet in the order of distance,—the Earth, on which we dwell: that habitation which, though it may appear so vast—so mighty—to our gaze, is but a speck in the great scheme of the universe. Could we but travel into space, and view the solar system as a connected whole, how small would

* The annual, diurnal, and libratory motions, explained hereafter.

our Earth appear, and how unworthy of the boastful importance which we are apt to attach to it! If there be inhabitants on any of the exterior planets, they see the Earth merely as a small star, shining by the light which she receives from the Sun, and which she reflects from her own surface.

That the Earth is round the proofs are many and easy: for, in addition to the gradual appearance, from the top downwards, of a ship coming into port, and the fact of the world having been sailed round, which amounts to practical conviction,—yet, as this sailing has always been in the direction of east and west, the Earth might be cylindrical, and this eastern and western circumnavigation still have taken place; but, in sailing southward, we observe that the fixed stars in the northern heaven sink down towards the horizon, and the southern stars keep on rising in the sky; the reverse taking place as we return northward. This circumstance is beautifully alluded to in the *Lusiad* of Camoëns, a Portuguese poem, relating to the discovery of India.

> O'er the wild waves as southward thus we stray,
> Our port unknown, unknown the watery way;
> Each night we see, impressed with solemn awe,
> Our guiding stars and native skies withdraw:
> In the wide void we lose their cheering beams:
> Lower and lower still the Pole-star gleams,
> Till past the limit, where the car of day
> Rolled o'er our heads, and poured the downward ray,
> We now disprove the faith of ancient lore;
> Boötes' shining car appears no more:
> For here we saw Calisto's star retire
> Beneath the waves, unawed by Juno's ire.

The latter part of this quotation implies, that when

the navigators had got some way below the tropic of Capricorn, they lost sight of the constellations Boötes and the Great Bear.

The Earth, however, like all the other planets, is not quite of a globular shape; and, before we proceed further, it may be desirable to explain why it is that none of the planets are precisely globular, but are somewhat flattened at two opposite sides, into a shape which is called an oblate spheroid, but which will be sufficiently comprehended, if we compare it to an orange.

All the planets, besides revolving round the Sun, have, as we said, a revolution on their own axes; that is, they spin round like a top. What may have been the original cause of this motion has never been discovered. We can only conclude that it was given to those bodies by the great Creator, for his own wise purposes, and according to his own fixed and inscrutable decree. Hidden as the cause of this motion is from us, we can, however, trace its effects in many important circumstances; one of which is, the oblateness, or flattening of the revolving bodies. There is a kind of force called *centrifugal*, occasioned whenever a spinning round is performed: this force tends to throw the body, or anything which rests upon that body, away from the centre as far as possible, and may be illustrated in a variety of ways. A pail of water may be suspended by a rope, and turned rapidly round in a vertical circle without wasting a drop of the water; although in every revolution, the pail, and the water which it contains, strive to recede from the hand, which is the centre of motion, as far as possible, during the revolution, by virtue of the *centrifugal*, or *centre-flying* force, which is imparted to them in proportion to the rapidity of

motion. When the pail is upside down, the natural tendency of the water is to be poured out towards the ground; but this tendency is counteracted by the centrifugal force, which tends to drive the water away from the central force which retains it. It is on a similar principle that a slinger propels a stone to a great distance: the hand is the centre of motion; and he turns the stone rapidly round in order to gain for it a centrifugal force, which shall carry it to a great distance, as soon as it is released. If we drive a wire through any round body, and make the surface of this body equally wet all over, and then spin it round by means of the wire, the moisture will be collected in greater quantity at those parts of the surfaces most removed from the wire; while, at the parts near the wire, the quantity will be diminished: the centrifugal force urges the fluid away from the central part to the part furthest removed from the wire; which part describes the largest circle in going round.

Now, the same line of argument will apply to a revolving planet: the surface of the Earth moves round its axis (an imaginary line, the extremities of which are called its *poles*), with a velocity of 1042½ miles per hour, at the equator, a line supposed to be drawn all round the globe, at an equal distance from the two poles and at right angles with the Earth's axis. It is clear, therefore, that the velocity of the rotation of any part of the Earth's surface must diminish as we recede from the equator and approach the poles. But, as the equatorial parts especially acquire such a vast centrifugal power, the effect of it is, that the Earth bulges out at those parts most removed from the axis of rotation. The extent, to which this bulging has been carried

in the case of the Earth, during the lapse of nearly sixty centuries, will be seen from the following dimensions:—the smaller diameter of the Earth, measured along the polar axis, is 7899 English miles; and the greater diameter, which is the diameter of the equator, is 7926 miles, which, therefore, exceeds the other by about twenty-seven miles: if we take the average of these two diameters, we may say that the Earth's diameter is about 7912 miles; consequently, the circumference of the Earth amounts to 24,899 miles.

Our planet, when in *perihelion*, that is, at *its nearest point to the Sun*, is about ninety-three millions of miles distant from the Sun, and about ninety-six millions of miles distant therefrom, when in *aphelion*, that is, *the point furthest removed from the Sun*. These two terms will be understood by referring to the ellipse, or oval, which is represented at page 39:—the Sun is situated, not in the centre, but in one focus of the ellipse; and when the Earth is nearest to the Sun's focus, she is said to be in *perihelion;* when furthest therefrom, in *aphelion*. Hence, its average distance from the centre of its annual motion, is about ninety-five millions of miles.

The path, which the Earth describes round the Sun, is, therefore, an orbit of about six hundred millions of miles; and this enormous distance she traverses at the rate of 68,000 miles an hour, or about nineteen miles in a second, in 365 days, 5 hours, 48 minutes, and 49 seconds, being the period to which we give the name of *year*. If the Earth did not revolve on her axis, we, who inhabit its surface, should see the Sun apparently making a revolution round the Earth in the course of a year: a revolution which, however, would be altogether

imaginary, owing to the fallacy of the evidence of our senses. The Earth moves in her orbit; but we cannot see that it is moving, because we are on its surface, and are moving in a like direction, and with a like velocity. The motion of the Earth is of a smooth, equable, and unimpeded kind; by which sort of motion, if we experience anything like it by land or water, our senses may be lulled into a forgetfulness of our being carried along, while the stationary objects on either side,—the hedges, trees, banks, &c.,—seem endued with motion, and glide rapidly past us. If this be the case with respect to the annual motion of the Earth round the Sun, how much more forcible is the application of this analogy to the diurnal motion of the Earth on her axis! The Sun, the planets with their moons, the comets occasionally, and innumerable fixed stars, are placed in an apparent hollow sphere around us; and as we come opposite to different parts of the heavens in succession by our diurnal rotation, it appears to us as if the whole of this concave sphere kept on revolving round our Earth.

The term of a *year*, just spoken of, is the time taken up by the Sun in passing, apparently, from a particular point of the ecliptic to the same point again: say, the first point of Aries, being one of the two points, where the equator and ecliptic cut each other. This is called the *solar*, or *tropical* year, the time it takes the Sun to visit the tropics and return to the equator: whereas, the time taken up by the Sun, in passing from a certain fixed star to the same star again, consists of 365 days, 6 hours, 9 minutes, and 12 seconds, and is called the *sidereal* year; the year as determined by observation of a particular star. This latter is 20 minutes, 23 seconds,

longer than the former; and is owing to a slow, but constant, alteration of the position of the equinoctial points.

The actual time in which the diurnal revolution of the Earth is completed, is 23 hours, 56 minutes, and 4 seconds; but, owing to the motion of the Earth in her orbit at the same time, it is twenty-four hours upon an average, throughout the year, before the Sun can pass from the meridian of a place to the same meridian again. This meridian implies a line drawn from north to south, going through any particular place, to which line the Sun becomes vertical every day at noon.

The axis, on which the Earth is supposed to revolve, is inclined to the plane of the Earth's orbit, or ecliptic, at an angle of about 66½ degrees. Now, as the plane of the equator is perpendicular to the axis of the earth, it follows that the plane of the equator is inclined to the plane of the ecliptic at an angle of about 23½ degrees. Very remarkable and important effects result from the rotation of the Earth on her axis, and from the obliquity of the equator with the ecliptic, which effects will occupy our attention more particularly in the next chapter.

We have already seen that the Earth is not now a perfectly geometrical globe; and it would strike us that, if there were no other cause to interfere with its due form, the existence of mountains and valleys on its surface is sufficient to disturb the tiny conception we have at first regarding

> This pendent world, in bigness as a star
> Of smallest magnitude close by the moon.
>
> MILTON'S *Par. Lost*, b. ii.

But our conceptions of the extent of the Earth's

Fig. 15.

THE PROBABLE APPEARANCE OF THE EARTH TO THE MOON.

surface, which are contracted when we compare the Earth with the universe, become enlarged by referring it to ourselves. Hence, by instituting an arithmetical comparison between the Earth and a globe of eighteen inches diameter, if we wished to form at its proper place on the latter, and in its proper proportion, the very highest mountain in the world, which is the Chumularee, belonging to the Himalayah range, in Asia, and 29,000 feet in height, the elevation on the artificial globe would be about the one-eightieth of an inch.

It is probable that the Earth serves, only in a more efficient manner, the same purpose to the Moon that the Moon serves to the Earth, undergoing all the changes which we see in the Moon, and appearing nearly thirteen times larger, and consequently much more brilliant. Its appearance to the Moon is represented in the accompanying figure. This representation is, of course, fanciful; and to estimate it fairly we must indulge ourselves in the supposition that the lunar inhabitants, if there be any, are, for the most part, in similar circumstances with ourselves.

We have before stated that the diameter of the Sun is 111 times as great as that of the Earth. Now this proportion makes the solar globe to be, as a whole, 1,384,472 times as large as the globe of the Earth; though the density of the latter is about four times as great as that of the former. The average density of the Earth is $4\frac{1}{2}$ times that of water: so that it would seem that the Sun is composed of matter somewhat more dense or consistent than water.

The Moon.

. . . . . Meanwhile the Moon
Full orbed, and breaking through the scattered clouds,
Shows her broad visage in the crimsoned East.
Turned to the Sun direct, her spotted disk,
Where mountains rise, umbrageous dales descend,
And caverns deep, as optic tube descries,
A smaller Earth, gives us his blaze again,
Void of its flame, and sheds a softer day.
Now through the passing cloud she seems to stoop,—
Now up the pure cerulean rides sublime.—Thomson.

When the poet wrote these beautiful lines, we can imagine, from the context, that he was under the influence of those feelings, which are produced in men by the aspect of the quiet, moon-lit scene of nature; when the tumults, excited by day, and the passions roused by intercourse with fellow-mortals, are becalmed by the clear, cold, silence, which pervades the open country; such as makes melancholy have something of a pleasing turn, when we love to walk forth—

To behold the wand'ring Moon,
Riding near her highest noon,
Like one that had been led astray
Through the heaven's wide pathless way,
And oft, as if her head she bowed,
Stooping through a fleecy cloud.

Milton's *Il Penseroso.*

We will consider chiefly the circumstances which relate to the Moon as a celestial body, independent of the Earth.

The Moon is about 2060 miles in diameter; that is, her diameter is rather more than a quarter of that of

the Earth, which is about fifty times the size of the Moon. Her mean distance from the Earth, as calculated from her horizontal parallax, is almost 240,000 miles; and she moves in her course round the Earth at the rate of about 2290 miles per hour.

The Moon shines by reflecting the Sun's light, as first supposed by Thales, the Grecian astronomer. Plato supposed that it was composed of fire; and Aristotle, that it shone by its own native light. The Moon's light has been found, as far as our means of observation extend, to be quite devoid of heat. This fact has been proved by concentrating 306 times the rays of the full Moon, when on the meridian, by a powerful burning-glass of three feet in diameter; the focus of which rays has not affected the most delicate thermometer. It has been shown by experiment that the light of the Sun is 300,000 times greater than that of the Moon. Now we will suppose that the heating power of the Sun, compared with that of the Moon, is in the same proportion. The direct rays of the Sun are capable of elevating the thermometer 237°. The Moon's beams would therefore raise the thermometer, according to this calculation, only $\frac{1}{1250}$th of a degree; and, if these Moon-beams were concentrated 306 times, the elevation of the thermometer might be $\frac{1}{4}$ of a degree. But, even this calculation is considered to be too favourable to the heating power of the Moon-beams, and cannot be borne out by experience.

The Moon, then, not possessing any heating rays, that are cognizable by man, does not seem likely to possess or exert any influence over the herbs, flowers, and other productions of the Earth, as was imagined by the old botanists. We read in the 33rd chapter of

Deuteronomy, verse 14, where Moses, the Jewish law-giver, speaks of the blessing of Joseph, that he refers to "the precious fruits brought forth by the Sun, and the precious things put forth by the Moon." We ought to observe that, in the original Hebrew, the word *moon* is used in the plural number; and in the next place, commentators have offered two senses of the latter phrase:—first, it may imply the productions of the ground made to spring up by the dews, which descend at night, when the Moon is visible; or, secondly, we may understand the productions of the Earth, which appear respectively in their different *months*, or *moons*; the former of these two words being only a derivation of the latter.

The inclination of the Moon's axis to the plane of the ecliptic is only about $1\frac{1}{2}°$; so that her seasons are permanent and without variety. The density of the Moon is considered to be somewhat greater than of the Earth.

The Sun and the Moon have always attracted the attention of mankind more than the other celestial bodies, owing to their greater apparent size, and direct influence upon our globe. The Moon, revolving round the Earth, is called the Earth's *satellite* or *attendant*. When the full Moon is viewed through a powerful telescope, her illuminated surface appears interspersed with dark spots and ridges, of every variety of shape, as represented in the accompanying figure; which kind of representation of the Moon was first sketched out by Hevelius, in the year 1645.

There are valleys, or hollows, which are supposed to be three miles deep and are surrounded by nearly circular margins, a phenomenon to which the Earth

Fig. 16.

cannot afford a parallel. The spots have been so carefully noticed, that a catalogue of 89 of them has been prepared, in which a description of the form and appearance of each spot, and of its exact position on the Moon's surface, is given. The spots have had fanciful names applied to them,—sometimes they have been named after distinguished individuals, while at other times they have been named after certain places on the Earth's surface, such as Byzantium, Caucasus, Sogdiana, &c. The heights of the mountains, which have been observed on the Moon's surface, are very variously stated by different authors, according to the modes in which the observations were made:—one of these modes was to measure the lengths of the shadows, cast by the mountains, in consequence of the light of the Sun coming in a particular direction, the shadows being then compared with the whole diameter of the Moon. The bright spots are held to be the tops of lofty mountains illumined by sunshine; two or three of which Dr. Herschel observed to be of a volcanic nature, and to emit flames and smoke. The best authorities make the highest of these mountains less than two miles in height. Generally speaking, the dark parts are thought to be water, and the bright parts land; the former absorbing, and the latter reflecting the solar rays: while, at the same time, many astronomers think that there is not much water in the Moon, owing to the usually serene appearance of her disk, which seems free from clouds and undisturbed by fogs and vapours. If there be little or no water in the Moon, this circumstance may account for the vast hollows just spoken of; which sort of appearance the Earth might present if the oceans and lakes were suddenly drained off. But, in respect of

the details of the surface of the lunar globe, there exists much variety of opinion among astronomers.

The Moon is presumed to have no atmosphere, or one which is of a very thin character, because there have not yet been observed any effects of refraction, whereby the forms of planets, when being *occulted*, that is, passed over and *hidden* by the Moon, would appear distorted just before the act of occultation. This effect would result from the star or planet being seen through the Moon's atmosphere. But there does not seem an universal opinion among astronomers on this point; as several have recently given accounts, which, if correct, would lead us to conclude that there was a lunar atmosphere; while others say decidedly that there is not: it seems, however, to be agreed that the atmosphere must be of a very rare character.

The Moon revolves in her orbit round the Earth at the same time that the Earth itself is revolving about the Sun: the consequence of which is, that the Moon traces a sort of curling line round the Sun; because, by the time the Moon has made one revolution round the Earth, the Earth has performed nearly one-twelfth part of her annual circuit round the Sun. The Moon goes round the Earth about $12\frac{1}{2}$ times in the course of a year; and the actual time taken up by the Moon in performing her circuit is about $27\frac{1}{3}$ days; but the time from new Moon to new Moon again is about $29\frac{1}{2}$ days. To each of these periods of time has been given the name of *month;* the former being called *periodical*, comprising the *period* of the Moon's course round the Earth; the latter *synodical*, or the month, as agreed upon by men in the infancy of society, and determined by *the coming together* of the Sun and Moon. The

reason why the latter is longer than the former is, that although the Moon might actually pass round the Earth in $27\frac{1}{3}$ days, if the Earth were still; yet, a longer time is consumed from one phase of the Moon to the same phase again, owing to the motion of the Earth in its orbit, in the same direction as the Moon's motion, from west to east; so that the extra $2\frac{1}{4}$ days are spent by the Moon in fetching up the overplus of the progress made in the mean time by the Earth.

The Moon revolves on an axis, and it is remarkable that the time of this revolution is just equal to the time which she takes to revolve round the Earth; a consequence of which is, that the Earth always has the same side of the Moon presented to it. The inhabitants, if any, on this side of the Moon have the Earth always before them, while those on the remote side of the Moon can never be blessed with the view of it. The disk, which the Earth must exhibit to the inhabitants of the Moon, having a diameter nearly four times as large as the Moon's, is more than twelve times as large as that which the Moon offers to the Earth. The Earth, must, of course, rise and set to the Moon, and go through the various phases of light, just as we see is done by our celestial attendant, owing to the motion of the Moon round the Earth; otherwise, the Earth will appear fixed in the heavens, relatively to the stars, because the Earth is the centre of the Moon's motion. The Earth too would turn on its axis nearly thirty times, while the Moon is moving once round,—a rapidity which must seem astonishing to the Lunarians. The phases exhibited to the Moon by the Earth, must be always the reverse of those exhibited at the same time by the Moon to the Earth, as will be evident from

inspecting the subsequent diagram. (Fig. 18.) We may imagine what must be the feeling of intense curiosity with which those on the further side of the Moon seek for information concerning the splendid orb, visible to the other lunar hemisphere. Suppose now that we, in England, were to hear of a splendid Moon, of vast dimensions, being visible to the inhabitants of the Sandwich Islands or New-Zealand, and that we ourselves were without a Moon, how eagerly would our navigators and travellers look out for the brilliant visiter, when they arrived at the line on the Earth's surface at which this spectacle became visible! At all seasons of the year we see the Sun and also the Moon: this arises from the circumstance, that although the Earth revolves on her axis, yet the time which she takes in that rotation is neither that which she takes to revolve round the Sun, nor that which the Moon takes to revolve round the Earth. This is a striking instance of the great effects which often result from what we should, at first sight, deem slight causes. We know not whether any living beings inhabit the surface of the Moon; but if such be the case, they must be divided into two portions, very unequally favoured, as regards the view of the Earth, one portion having it always in sight, while to the other portion the Earth is altogether invisible.

From the foregoing statements it will be seen that one day and one night are completed to the inhabitants of the Moon during one of her revolutions round the Earth. Hence the lunar day and night must be each as long as $14\frac{1}{4}$ of our days. One side of the Moon must have the full glare of the Sun's light and heat, almost unmitigated: the lunar atmosphere, if there be

any, being very rare, and therefore not holding clouds suspended in it, while the contrary side of the Moon is enveloped in almost profound darkness and intense cold; this must especially be the case at that side of the Moon which the Earth never sees. From this will result, also, the lunar summer and winter, coincident with the lunar day and night; for such must be produced merely by the Moon's rotation on its axis, the inclination of this axis to the ecliptic being, as we said, so small as to produce no change of seasons.

Though, as was before said, we see only one side of the Moon, yet there is occasionally seen somewhat more than an exact hemisphere, which effect is termed *libration*, a word implying a *poising*, or *oscillation*, of the body of the Moon, owing to certain disturbing causes.

When a little of the further side of the Moon on either side is seen, owing to the irregularity of the Moon in her orbit, by reason of the attractions of the Sun and the Earth, this effect is termed the Moon's *libration in longitude;* and when, owing to the Moon's axis not being quite perpendicular to her orbit, a little of the further side of the Moon is seen at either of her poles, this effect is called the Moon's *libration in latitude*. Owing to the causes which produce these effects, the Moon's motion is the most irregular and complicated of any of the celestial bodies. Moreover, we do not exactly see the same face of the Moon when she is in the horizon as when she is in the zenith, which difference is termed *diurnal libration*.

The phenomenon of the HARVEST-MOON has naturally attracted the attention of mankind at all times; who, feeling the benefit of the Moon's light more especially in the autumnal months, have considered it a

token of the goodness of God, in giving them a greater share of natural light at a time, when it was so necessary to use diligence in getting in the fruits of harvest.

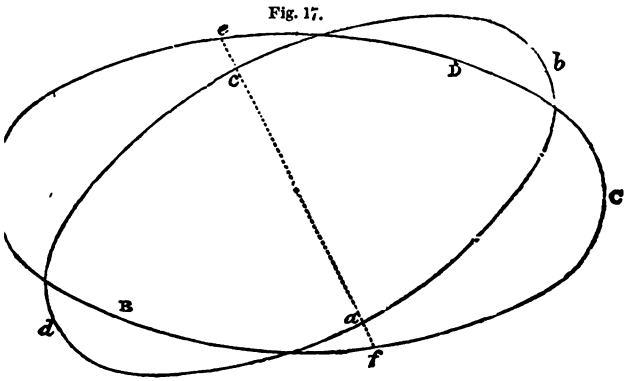
But, as it has pleased the Almighty to ordain physical causes to act in His moral government of the world; so also in this instance;—not, however, leaving us to be less grateful to His superintending Providence. Now, in the month of September, when the Sun is in the constellation Virgo, and the Moon in Pisces, the latter rises full every evening together, soon after sunset, with very little difference of time. The like occurs in October, when the Sun is in Libra, and the Moon in Aries. The former is called the Harvest-Moon, and the latter the Hunter's Moon.

The phenomenon of the Moon's rising with very little difference of time for several days together, occurs likewise in other months besides September and October; as the Moon is in the constellations Pisces and Aries every month. But, as at one season the Moon is new, and at others the Moon is in her quarters, her rising is then scarcely regarded. The fact of the Moon thus rising every evening with but little difference of time, is due to the smallness of the angle made in those months, by the ecliptic and horizon. This is easily and beautifully exemplified with the celestial globe.

The orbit of the Moon is inclined to that of the Earth, or the ecliptic, at an angle of about 5°; and the points, where these orbits cut each other, are called *nodes*, from the Latin *nodus*, a *knot*. This observation applies likewise to all the planets in their crossing the ecliptic, or orbit of the Earth. The Moon and the different planets are *above* the orbit of the Earth, during

one-half of their orbital revolutions, and *below* the Earth's orbit during the other half. In figure 17, let A B C D represent the ecliptic, and *a b c d* the orbit of Mercury. The dotted line *e f* is called *the line of the nodes*, because it passes through those parts of the respective orbits which cut each other, or are on a level with each other, which level is *e c a f*. The planet, in moving round from west to east, goes in the direction *a b c d; a* is, therefore, called the *ascending* node, *c* the *descending* node.

Fig. 17.



THE NODES OF A PLANET.

The word *disk*, so frequently used in reference to the Sun and Moon, implies a flat circular appearance, such as is presented by the Sun, Moon, and other heavenly bodies when magnified; it is derived from the Greek word for *hurling*, the disk being a flat circular piece of metal, used in this exercise; we call it a *quoit*.

We shall now notice in order those phenomena presented by the Earth and Moon, which are dependent

on their relative positions conjointly with the Sun: these may be considered as of three kinds; 1st, the Phases of the Moon; 2nd, Eclipses of the Sun and Moon; 3rd, Tides.

I. Phases of the Moon.

We have already stated, in general terms, the reason why an opaque body, such as a planet, must necessarily exhibit phases similar to those of the Moon. We may here add, that this observation applies especially to bodies whose orbit is within, or next to, that of the Earth. The planets Mercury, Venus, and Mars, have been found to exhibit phases. The more distant planets present always a full face, owing to the great scope of their annual motions. The phases of the Moon, our nearest neighbour in the sky, are, however, so extremely interesting as a phenomenon, which bears reference to the Earth, that we deem it desirable to present in this place a figure illustrative of its causes and nature.

Let us imagine that S represents the Sun (supposed to be at a great distance off), that O represents the Earth, and A B C D, &c., the Moon at different parts of her orbit round the Earth. We will assume, in the first instance, that the Moon is at A; in this position it will be perceived, that the enlightened half of the Moon is turned completely away from the Earth, while the dark half is presented towards the Earth.

This results from the principle, that only one half of a globular body can be illuminated at one time, by a light proceeding from only one source; as, therefore, the illuminated half of the Moon is directly towards

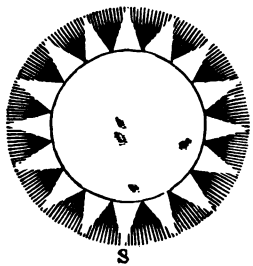
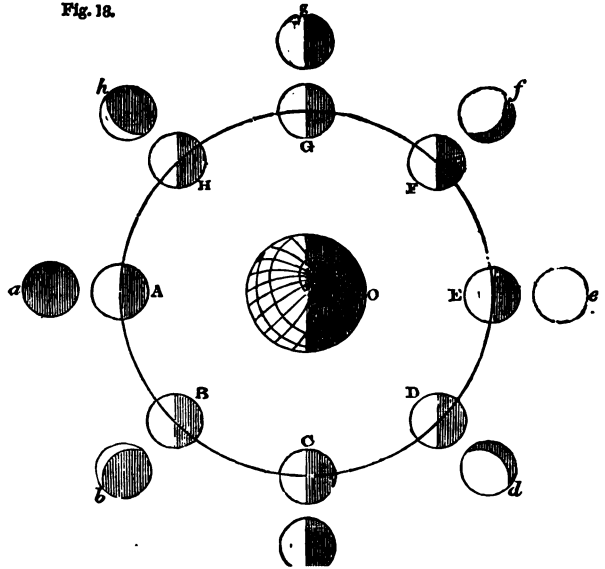


Fig. 18.



the Sun, and the dark half towards the Earth, it follows that an inhabitant of the Earth cannot see the Moon at all; this fact is represented by the black circle *a*, and whenever such is the case, the moon is said to be *new*, or in conjunction.

In about three and a half days from this time the Moon will have moved round in her course to the position B, which is called the first octant, or the first eighth part of her orbit. In this position the enlightened side is, as before, towards the Sun, but the dark side is not turned directly towards the Earth; the inhabitants of the Earth see the Moon at some distance on the eastern side of the Sun, and the consequence of this is, that they catch a glimpse of the Moon's illuminated part. The illuminated part thus observed, presents the appearance of a crescent, and is represented by *b*. The points of this crescent are called the Moon's *horns*, or *cusps;* the latter word being derived from the Latin *cuspis*, a *point*. If we take note of the day on which a new moon occurs, as stated in an almanac, and watch for the actual appearance of the Moon about three days afterwards, we shall find that it presents the form of a luminous crescent, convex on one side, and concave on the other, and, moreover, that the convex side is invariably turned towards the Sun.

After passing that position the Moon travels on to the position C, when she is said to be *in quadrature*,—that is, she has performed a quarter of her revolution round the Earth. In this position it will be found, that one half of her illuminated surface is visible to an inhabitant of the Earth, or that she appears as a semicircle, as at *c;* this occurs in about a week after her conjunction.

Proceeding in her orbit, she arrives at the position D, which is so far removed from the position A, that nearly the whole of the illuminated surface is visible to the Earth, at O. In this position the Moon is at her second octant, and presents an appearance such as *d*, in which about three-fourths of her illuminated surface is visible. This is the gibbous phase. The word *gibbous* is derived from a Hebrew word, implying *prominence* or *convexity*.

In another period of about three and a half days, we find the Moon in the most favourable position for being viewed from the Earth. This position is at E, which is on the further side from the Sun, which illuminates, as before, one half of the Moon's surface, and that half is visible to the Earth at O. The Moon is now *full*, or in opposition; and its appearance, as viewed from the Earth, is a luminous circle, as *e*.

After this period the Moon begins to wane, or to diminish in the apparent extent of its illuminated surface. When she reaches the position F, she presents to the Earth the same amount of illuminated surface as at D; but the flattened, or imperfect edge, is turned somewhat round, so as to maintain its constant character of being away from the Sun. Its appearance to the eye is represented by *f*. This is the third octant.

Shortly afterwards it attains that position which is termed the last quarter, and which is represented at G. Here the general resemblance is to the position C, when the Moon was in the first quarter; and it is represented, as seen by the eye, at *g*. The last octant is at the point H, when the Moon has performed seven-eighths of her orbit round the Earth, and her appearance is that of a faint crescent of light as at *h*, which

is equal in extent and brilliancy to the crescent *b*, which she presented about three weeks previously.

From this point she proceeds again to the point A, when she becomes again invisible to the Earth, on account of her illuminated surface being turned wholly away from the Earth: she may again be represented by the black circle *a*, and again obtains the name of New Moon, and is in conjunction.

Thus it appears that the different phases, or appearances of the Moon, admit of being satisfactorily explained on the twofold principle, that she is an opaque body, reflecting the Sun's light, and that she revolves round the Earth from New Moon to New Moon. It is necessary here to observe, that although we are in the habit of considering the full Moon as a perfect circle, or disk of light, it is not so in reality. When we see the full Moon, she is either raised a little above, or depressed a little below, the straight line joining the Sun and Earth, and, therefore, there is a small portion of her illuminated surface lost to, or turned away from, the Earth; this portion is at the upper part, when the Moon is above the line of which we have spoken, and at the lower part when she is below that line. When, however, the Moon is exactly in the direction of this line, or, in other words, when the Sun, the Moon, and the Earth are all in one straight line, some very remarkable effects are produced, which, under the name of *Eclipses*, have attracted a large share of attention in all ages. The principle is similar to that which we alluded to, in the case of the transits of the inferior planets; but when the Sun, Moon, and Earth are all concerned, the effects are more imposing upon the mass of mankind. In proportion to the ignorance of the

cause of any operation of nature, is the amount of speculation and alarm respecting the effects. Among the nations of antiquity the occurrence of an eclipse was sufficient to suspend the rage of battle, the heat of intestine discord, and most of the common operations of life. The superstition of the ancients referring the apparent changes in their deities, Sol and Luna, to their own conduct, they betook themselves to prayer and sacrifice to appease the offended gods; and when the eclipse had passed away, they believed the celestial powers to be propitiated.

By the introduction of Christianity many of the absurd notions of this sort held by the ancients were dispelled, or greatly modified; but yet, until Astronomy was well understood, the fear of something supernatural constantly haunted the great bulk of mankind, believing, as the savage races of mankind do now, that when the motions of these three celestial bodies bring them into a line, the Sun

> . . . . . from behind the Moon
> In dim eclipse disastrous twilight sheds
> On half the nations, and with fear of change
> Perplexes monarchs.
>
> MILTON'S *Paradise Lost*, b. i.

The phenomena of the heavens have often been resorted to by designing men, to impose upon the credulity or fears of the unintellectual part of mankind. We read that Columbus, when in the island of Jamaica, in the year 1503, was reduced by dread of famine to resort to an imposition of this sort to procure provisions. Columbus and his crew, having been wrecked, had consumed their small stock of provisions, and

having to depend upon the natives, with whom many untoward circumstances had prevented them from being upon good terms, it struck Columbus, who had a great knowledge of astronomy, that an approaching eclipse of the Moon might serve his purpose of awing the natives. He, accordingly, summoned their chiefs to a council on the evening of the eclipse, and told them that the Deity of the skies, whom they served, was angry with the Indians for withholding provisions from the Spaniards; that the Indians would be punished in a signal manner; in token whereof the full Moon, then riding in majesty across the celestial dome, would be deprived of her light, and held in black durance. Some treated this announcement with contempt, while others were alarmed, but all were naturally anxious. When they at length saw the black shadow of the Earth seizing the Moon within itself they were all horror-struck, and, hastening to the crew with provisions of all sorts, they begged the intercession of Columbus with the celestial Deity, that the Moon might be restored, promising to serve Columbus faithfully ever after. Columbus, after retiring for some time to consult the Deity, as he said, promised them that the curse would be taken off from them; and that, as a sign, the Moon would emerge from her confinement; which, when the Indians saw again traversing the heavens, they adored the astronomer, believing him to have supernatural gifts, and to hold an intercourse with heaven, whereby he was informed of what would take place in the skies. The Spaniards suffered no more upon this occasion through famine.

It appears that some of the earliest efforts of astronomers were directed to the prediction of eclipses: how

far the power of predicting the occurrence of an eclipse was really possessed by the early Chinese, Hindoos, and Chaldæans, seems to be a matter of much dispute among the learned; sufficient evidence remains, however, to show that extraordinary attention was bestowed upon these phenomena. To attempt to explain the manner in which the astronomer is enabled to predict the return of an eclipse, would be altogether foreign to our present purpose; but we shall endeavour to show in what way the obscuration of light, which obtains for the phenomena the name of an *eclipse*, takes place.

II. Eclipses.

The first point to which we must direct our attention is this:—Why does not an eclipse take place at *every* new and full Moon? The answer to this is, because the Moon's orbit is inclined to the Earth's orbit; that is, the Moon in moving round the Earth, does not keep in the same plane as that in which the Earth moves round the Sun. The two planes are inclined to each other at an angle of about $5\frac{1}{4}°$, so that in one part of her orbit, the Moon is above the plane of the Earth's orbit, and in another part she is below that plane. Now, it is obvious, that only at the times she is in either of her nodes is she in the plane of the Earth's orbit.

Hence, it is only when the Moon is *at* or *near* one of her nodes, at the time of new or full Moon, that an eclipse can happen; so that, if she be far removed from her nodes at new or full Moon, she is altogether above or below the line which joins the Earth and the Sun; but if she be exactly at the node, there will be a *cen-*

tral eclipse, and if she be within certain limits on either side of one of her nodes, there will be a *partial* eclipse.

SOLAR ECLIPSES.

This being premised, we are in a condition to understand the phenomenon of an eclipse of the Sun, to which we shall now more particularly give our attention. Let s (figs. 19 and 20,) represent the Sun, E the Earth in its orbit, and *m* the Moon in conjunction. A circle surrounds the Earth, which may be considered to represent the Moon's orbit. If the Moon were not present, exactly one-half of the Earth's surface would be illuminated by the Sun; but an obstruction to the Sun's light is offered by the Moon interposing. We have, therefore, the Moon *m* between the Earth and the Sun, and at or near one of her nodes; so that she is not only in the same vertical plane as the Earth and the Sun, but in the same right line with them. If they be not precisely in the same right line, as shown in our figures, there may, at any rate, be a *partial* eclipse of the Sun, if the Moon be within 17° 21′ of her node at the time of conjunction, or new Moon.

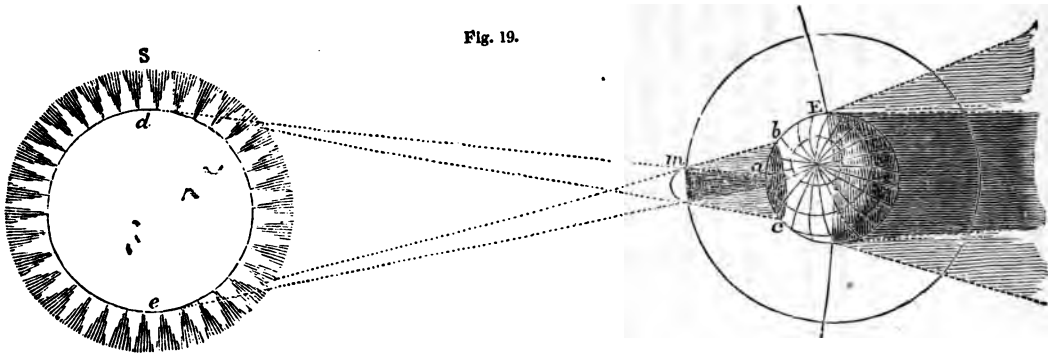
Now, when we hold a ball before a candle, not only is there one-half of the surface of the ball in darkness, but there is a long shadow behind the ball, occasioned by the interruption which the ball presents to the free progress of the light in that direction. If we hold a second object in this shadow, we cannot see it by the direct light of the candle; the view which we may obtain of it being by light reflected from other parts of the room; and if we were in a large open space where no objects were present to afford this secondary

reflection, we should find the object immersed in the shadow to be almost entirely invisible. Reasoning thus in the case of the Moon and the Earth, we find a strict analogy: a flood of light is shed by the Sun on the Moon at *m*, by which its front surface is wholly illuminated, and its hinder surface kept in the shade: there is also a shadow cast behind the opaque body of the Moon, the extent of which shadow depends conjointly on the sizes of the Sun and Moon, and the distance between them. This shadow is of two kinds, the *umbra** and the *penumbra;* the former being the darker of the two: the reason of this difference is, that the umbra covers a portion of space *wholly* deprived of the Sun's light, while the penumbra covers that portion of the Earth's surface which has a view of *part* of the Sun's disk. Were the Sun but a luminous point, this distinction would not occur; but, as he has a very considerable diameter, and the Moon is very small compared even with the Earth, it follows that there will be no eclipse to places out of the penumbra; that places in the penumbra will have the Sun partially eclipsed; and that places in the umbra will see a total, or an annular, eclipse of the Sun; the latter depending upon the distance of the Moon from the Earth. The first of the two subsequent figures represents a *total*, the second an *annular* eclipse.

The Moon *m* being exactly between the Earth and the Sun, throws her dark conical shadow *m a* towards the Earth, which shadow, in the first case, reaches the Earth, and in the second falls short of it.

* *Umbra* is the Latin for *a shadow; penumbra* implies *a partial shadow.*

Fig. 19.



TOTAL ECLIPSE.

If, now, we suppose an inhabitant of the Earth to be situated at the point *a*, (fig. 19,) he would witness a total eclipse of the Sun: he will be situated in the shadow of the Moon, and the body of the Moon will completely hide the Sun from his sight: this will be evident, when it is seen that he will be in the shadow, between the lines *d a*, *e a*. If another inhabitant of the Earth were situated at any point between *b* and *a*, or *a* and *c*, he would see a partial solar eclipse; that is, the black disk of the Moon would appear to cut off a portion of the luminous surface of the Sun. The parts of the Earth beyond *b* and *c*, on either side, are out of the effects of the eclipse: the people beyond *b* and *c* see the whole disk of the Sun, as is plain by observing the direction of the lines *b e* and *c d*.

If the Moon were at a constant distance from the Earth, and the Earth at a constant distance from the Sun, a central eclipse of the Sun would always present the same features to an inhabitant of the Earth; but such is not the case: the Earth is about three millions of miles nearer to the Sun in December than in June, on account of her being at that end of her elliptical orbit which is nearest to the Sun; consequently the Sun appears larger, or subtends a larger angle, at the former period than at the latter. Again, the Moon's orbit round the Earth is likewise elliptical; and although we are accustomed to say that the Moon is about 240,000 miles distant from the Earth, yet, when we wish to determine the distance at different times, it is found that the Moon's greatest distance from the Earth is about 251,000 miles, and her least about 227,000. Now, if the Moon were in *perigee* (that part of her orbit nearest to the Earth), and the Earth were in

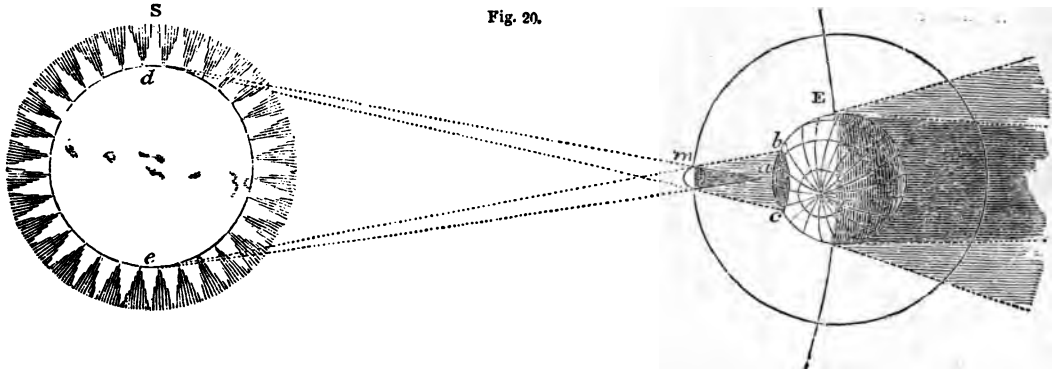
aphelion (that part of her orbit furthest from the Sun), at the time of a central solar eclipse, the eclipse would be total, because the apparent diameter of the Moon, as seen from the Earth, would be greater than that of the Sun. But if the reverse were the case; if the Moon were at her greatest, and the Sun at his least, distance from the Earth, at the time of a central eclipse, then the eclipse would be annular*; that is, a ring of the Sun's light would seem to surround the dark body of the Moon, in consequence of the Sun having at that time a larger apparent diameter than the Moon. These differences would not occur, were it not that the apparent dimensions of the Sun and Moon, as seen from the Earth, are so nearly equal.

Hence it will be seen, by inspecting figure 20, that, in an annular eclipse, no part of the Earth can be enveloped in the Moon's umbra, owing to its not reaching the Earth; and the solar ring can be seen only by that part of the Earth where the umbra would have fallen, if the Moon had been nearer the Earth; that is, under the point *a*, where a straight line would reach which had passed through the centres of the Sun and Moon. The part of the Earth out of this spot, but between *b* and *c*, sees only a partial eclipse, and those beyond *b* and *c* see none at all.

In order to obtain some means for estimating the magnitude of an eclipse, the diameter of the Sun or Moon is supposed to be divided into twelve equal parts, called *digits;* so that, when it is said that such a number of digits was eclipsed, the meaning is at once known: the Moon was not in a node at the time of the eclipse,

* So termed from *annulus*, the Latin for *a ring*.

Fig. 20.



ANNULAR ECLIPSE.

the eclipse was therefore partial, not central, and the number of digits indicates to what extent of surface the eclipse advanced.

Calculations have been made as to the longest time that a solar eclipse can be either total, or annular, under the most favourable circumstances; and it has been found that 12 minutes 24 seconds is the longest time of an annular eclipse, and 7 minutes 58 seconds the longest time of a total eclipse.

The periods which the Earth and Moon take to perform their respective revolutions, and the degree of obliquity between their orbits, have enabled astronomers to calculate how many eclipses may occur in a year. There must be two eclipses of the Sun in every year, and the number may be as high as five, but it cannot be greater. No solar eclipse is visible in every part of the portion of the Earth which is turned towards the Sun, because the shadow of the Moon is too narrow to take in the whole diameter of the Earth at once, as may be seen in the preceding figures. A solar eclipse cannot be total at the same moment to a portion of the Earth more than 180 miles in diameter; but it may be partial at the same moment to a portion of the Earth 4900 miles in diameter. We may further observe that a solar eclipse does not happen at the same point of time at all places where it is perceived: it appears earlier to those persons situated towards the west, than to those situated towards the east, because the motion of the Moon and of her shadow is from west to east. Moreover, the extent of solar obscuration is different at different latitudes on the Earth's surface according as we may suppose a spectator to be more or less distant from the line which connects the three bodies in question.

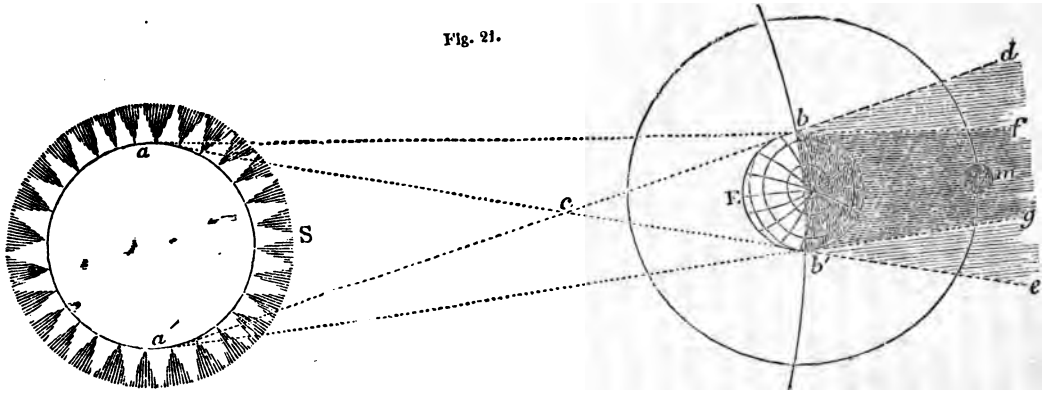
Lunar Eclipses.

As the solar eclipse was owing to the opaque body of the Moon hiding the light of the Sun from the Earth, and took place when the Moon was new, or in conjunction; so the lunar eclipse is due to the opaque body of the Earth hindering the solar rays from reaching the Moon, and takes place when the Moon is full, or in opposition.

In the following figure, s represents the Sun, e the Earth, *m* the Moon in opposition. The Sun, shining upon the Earth, causes a shadow to be thrown behind, which has the form of a cone; that is, it tapers to a point like a sugar-loaf. The reason why the shadow thus tapers to a point is, that the Sun is so much larger than the Earth. The distance of this point, or the total length of the Earth's shadow, is about 840,000 miles, when the Earth is nearest to the Sun; and about 870,000 miles, when she is at her furthest distance therefrom: it follows, therefore, that if any body come behind the Earth, in a right line with the Sun and the Earth, and not at a greater distance from the Earth than has just been named, that body will be immersed in the Earth's shadow.

This is the case with the Moon: we have seen that she is, on an average, about 240,000 miles distant from the Earth; and that she revolves round the Earth in a plane nearly coincident with the plane of the Earth's orbit. In our figure the shadow of the Earth is represented as having a conical tendency; if now the Moon *m* were beyond the apex of this cone, she would altogether escape from the Earth's shadow, but, as part

Fig. 21.



A LUNAR ECLIPSE.

of her orbit (which is represented by the circle,) is between the base and the apex of the shadow, the Moon is necessarily immersed in the shadow, and we thus have the phenomenon known as an eclipse of the Moon. If the Moon happen to be at one of her nodes at the time of full Moon, then we have a central and total eclipse; but if she be at any part of her orbit not exceeding 11° 21′ from the node, the eclipse will be partial. In the latter case, the three bodies cannot be in a perfectly straight line; so that the Moon dips more or less of its body into the shadow of the Earth, but not the whole of its body.

Some time before the commencement of an eclipse of the Moon, she is seen to be partially obscured, as if a mist covered the illuminated surface: this arises from the circumstance that she has to go through the Earth's penumbra, or partial shadow, before her immersion in the umbra, or real shadow. In our figure, rays of light from the two extreme edges of the Sun $a\,a'$, pass by the edges of the Earth $b\,b'$, (having previously crossed at c,) and go on in the direction $b\,d$ and $b'\,e$: but still the upper part of the penumbra $d\,b\,f$, receives light from the upper part of the Sun, although the Earth prevents it from receiving light from the lower part; and, again, the lower part $g\,b'\,e$ of the penumbra receives light from the lower part of the Sun, although the upper rays are also excluded by the Earth. From this circumstance, therefore, the real shadow is surrounded by a partial shadow, which imparts to the Moon the dusky appearance just mentioned, which duskiness becomes more decided as the Moon approaches the real shadow, and receives still fewer rays from the Sun. If there be inhabitants in the Moon, they, of

course, see a solar eclipse; and, while they are in the Earth's penumbra, the Sun appears to them partially eclipsed, which solar eclipse increases until the Moon enters into the Earth's umbra; when the Sun appears to the Moon, and the Moon appears to the Earth, totally eclipsed.

By comparing the foregoing circumstances, we find that a solar eclipse can be visible to only a portion of the enlightened hemisphere of the Earth: while a lunar eclipse may be seen by half the globe of the Earth. Moreover a lunar eclipse always begins on the eastern edge of the Moon, because her motion is from west to east; so that her eastern edge first enters into the shadow of the Earth: but, in the case of a solar eclipse, the dark body of the Moon appears first on the western limb of the Sun, on account of the motion of the Moon from west to east, as mentioned in the former case.

During a total, or large partial eclipse of the Sun, the dark side of the Moon is not wholly invisible. We can, therefore, descry its general outline, owing to the Sun's light being reflected strongly from the surface of the Earth to the Moon; and this reflected light is again reflected from the Moon, and constitutes the faint light on her surface seen during a solar eclipse, and also in a very interesting manner, when the Moon is only two or three days old. The disk of the Earth appearing to the Moon nearly thirteen times as large as the Moon appears to us, the light which the Earth gives the Moon must be very great. Now, when the Moon is two or three days old, the Earth appears as a large gibbous figure of light to the Moon; and so we see not only the sun-lit part of the Moon, but also the rest of its disk, seeming of a dirty white plaister colour. As

the light of the Sun increases upon the disk of the Moon, the Earth's light to the Moon wanes, and we no longer notice this appearance.

In a total eclipse of the Moon this body is still seen, even when enveloped in the shadow of the Earth, by reason that the rays of light from the Sun are bent round the margin of the Earth by the refracting power of its atmosphere, and are thus carried on through space till they arrive at the Moon; from the surface of which they are again reflected. It is further evident that an eclipse of the Sun cannot be identical as to time and appearance, to any two spectators situated at different points on the Earth's surface; because the Sun loses no light, but is only hidden, as it were, by a screen, scarcely, or just big enough to hide it: but an eclipse of the Moon is identical as to time and appearance, because it loses its light, and that too, at a certain precise point of time:—that is to say, we may see the Sun at the time of a solar eclipse, and be ignorant that he is eclipsed; but a lunar eclipse is seen by all who see the Moon.

Hence, though the solar eclipses are more numerous than the lunar, the latter are more likely to be observed, being visible to a whole hemisphere. The usual number of eclipses is about four, two of the Sun and two of the Moon; but there cannot be more than seven, nor fewer than two: when there are only two, they will be of the Sun, as is the case this year.

A lunar eclipse cannot last longer than $5\frac{1}{2}$ hours, from first entering into the Earth's penumbra to quitting it: she cannot be eclipsed partially and totally more than $3\frac{3}{4}$ hours: and she cannot be totally eclipsed more than $1\frac{3}{4}$ hours.

CHAPTER VII.

THE SEASONS. THE CIRCLES OF THE GLOBE. PARALLELISM OF THE EARTH'S AXIS. ALTITUDES OF THE SUN IN SUMMER AND WINTER. CONSTELLATIONS. THE ZODIAC. EQUINOXES,—PRECESSION OF. MOTION OF THE SUN IN THE SIGNS OF THE ZODIAC. DAY AND NIGHT. SOLSTICES. THE HORIZON. REFRACTION.

The Seasons.

Wished Spring returns; and from the hazy south,
While dim Aurora slowly moves before,
The welcome Sun, just verging up at first,
By small degrees extends the swelling curve!
Till seen at last for gay rejoicing months,
Still round and round, his spiral course he winds,
And as he nearly dips his flaming orb,
Wheels up again, and re-ascends the sky.

THERE are but few phenomena presented to the notice of man more beautiful, and, at the same time, more instructive to him, than the regular succession of seasons, and the varied benefits which they confer. The cold and bleak temperature of our winter is rendered less rigorous by the artificial processes by which we obtain warmth within our dwellings; but still the genial and refreshing air of spring is looked forward to by all as a delightful change from the dreariness of winter. The pleasing associations connected with spring, when both animal and vegetable life seem to acquire new vigour, and a new lease, as it were, of existence, would not alone suffice for the wants, either natural or artificial, of man. The summer's Sun is required to ripen and bring to perfection

the fruits of the Earth, whether to be used directly by himself as articles of food, or to nourish those animals which subsequently furnish him with diet. The summer's Sun is also necessary to melt the ice, which makes the polar regions one sterile and dreary waste, unfit alike for almost every species of animal or vegetable. Were it not that the genial warmth of the summer's Sun dissolves large portions of ice, the frozen regions would gradually extend their boundary towards the equator; and those countries now called *temperate*, and which present fit localities for the habitations of man, would become ice-bound, and consequently uninhabitable.

But do our wants cease here? should we be content with constant summer? No; the grass would become withered, the flocks would lose the food with which they were for a while nourished, the brooks and rivulets would be dried up, pestilential diseases would ensue from the putrefaction of animal and vegetable bodies, and man himself, enervated and debilitated by excess of heat, would droop as if the vivid spark of life were sinking out. These results are prevented by the wise ordinations of Providence, by which summer is succeeded by autumn; a season which at the same time softens the descent from summer to winter, and brings to perfection those fruits which are to serve for the good of man, and other animals, during the remaining portions of the year.

Thus, then, does each season bring with it its joys and advantages; and thus are we taught to admire the exquisite mechanism and adjustment of the heavenly bodies, by which these joys and advantages are imparted to us. But how are these seasons brought about? and why is it that the Sun sheds such a vary-

ing amount of cheering influence on the Earth at different seasons? The answer to this question is admirably calculated to show what wonderful effects spring from apparently small causes. The reason for the succession of the various seasons is to be found in the simple circumstance, that the Earth does not revolve on her axis in the same plane in which she revolves round the Sun; if those two planes coincided, we should have no variety of seasons; the same intensity of heat or of cold would be experienced at the same place, at every season of the year. This important circumstance we now proceed to explain and illustrate.

Before we enter upon that inquiry, however, it will be necessary to describe certain circles, which are supposed to be drawn on the surface of the Earth, and in doing so we must refer to the figure of the globe, page 175.

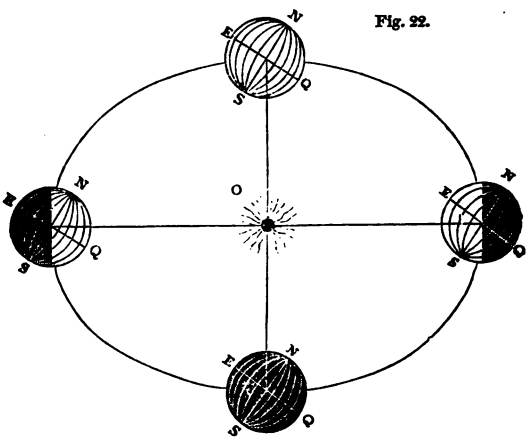
The Earth is, as before stated, nearly a perfect globe, of which the equatorial diameter is a little greater than the polar; and it has likewise been observed, that this globe, besides its revolution round the Sun in the course of a year, revolves on its own axis from west to east, once in every twenty-four hours. The two ends of this axis are the north and south *poles*, P and Q. The circle which surrounds the Earth, exactly midway between the two poles, is called the *equator*, E R. Another line crossing the equator in an oblique direction, but not given in the figure, is called the *ecliptic*, from the circumstance that whenever an eclipse occurs, either solar or lunar, the Sun, the Moon, and the Earth are all quite, or very nearly, in this plane. The ecliptic is a circle which, like the equator, goes round the Earth, and represents the apparent p th of the Sun

in the course of a year; that is, if a body were held exactly in a right line between the centre of the Sun and the centre of the Earth, the shadow of that body would travel along the ecliptic. These two circles, the equator and the ecliptic, are called *greater* circles, because their planes pass through the centre of the Earth, and divide the Earth into *equal* parts; whereas, all other circles are denominated *less* circles, because their planes divide the Earth into two *unequal* parts. There are also two circles which surround the Earth, parallel to the equator, and at a distance from it equal to about $23\frac{1}{2}°$. These are called *tropics*, from a Greek word which implies *turning*, as the Sun, when it has arrived at those parts, begins then to turn away again northward or southward, as the case may be; the circle which is nearer to the north pole being the tropic of Cancer, and that which is nearer to the south pole being the tropic of Capricorn. The position of these two circles is determined by the greatest distance which the ecliptic recedes from the equator; and they receive their name from the circumstance of the Sun being at the time in the constellation which gives the name to the tropic. There are also two small circles which surround the poles, at a distance from the poles exactly equal to the distance of the tropics from the equator. The *arctic* circle is that which surrounds the north pole, at a distance of $23\frac{1}{2}°$; the *antarctic* circle is that which surrounds the south pole. The term *antarctic* signifies *opposite to the arctic*, which latter term is derived from the Greek for a *bear:* the little bear is a constellation over the north pole of the Earth.

Now, in the subjoined diagram, we observe an oval line, which the Earth describes annually about the Sun

at O, or which the Sun appears to describe round the Earth. The Earth moves round this orbit in a year, and we have the position of the Earth in that orbit at four different periods of the year, about three months asunder. It will be seen that the axis of the Earth N S is inclined towards one side, and that it remains parallel throughout the whole of the Earth's revolution; that is, that there is exactly the same obliquity, or sloping direction, at all seasons of the year; this causes the equator to form with the ecliptic an angle of about $23\frac{1}{2}°$.

Fig. 22.



Let us now suppose the time of the year to be the 21st of March, and let us trace the progress of the Earth in her annual orbit. She is then at the upper part of the figure in the position which affords the northern spring, and the Sun is at exactly the same distance from both poles; that is, if the centres of the Sun and the Earth were connected by a right line, this line would pass through the equator E Q, and

would therefore be equidistant from the two poles. Now it is not difficult to see that in this case the Sun imparts just as much heat to one pole as to the other, affecting either hemisphere alike. At about the 23rd of June the Earth is at the left, and gives the northern summer. Here the Earth is actually further from the Sun than it was three months before: but the excess of heat at this latter period is due to a circumstance altogether separate from the actual distance of the Sun. The obliquity of the axis of the Earth is the important circumstance to which we have to keep our attention. We perceive that in the northern summer, the north pole is nearer to the Sun than the south pole: hence a greater amount of heat is received from the Sun by the northern part of the Earth than by the southern at this period. This is the sole origin of the results of the seasons, *summer* and *winter:* the large amount of heat received by the northern hemisphere, in comparison with that received by the southern, produces the season of summer to the former, and winter to the latter. If at this season we mark the boundary line between the enlightened and the dark hemispheres of the Earth, it will be seen that this line will just graze the polar circles: it will likewise be seen, that if we draw a line through the centres of the Sun and Earth, that line will pass through the tropic of Cancer.

We next find the Earth in the lower position which she attains about the 21st of September, when the northern autumn is felt. We observe that the Earth's position is such as it was in the spring, when the two poles were exactly equidistant from the Sun. Here then we have the season of autumn, in which the direct light and heat of the Sun are equal to what they are in spring.

This is not what we are in the habit of supposing, because the sensation of warmth is decidedly greater in autumn than in spring; but the apparent contradiction is thus accounted for: although the *direct* heat of the Sun is the same in autumn as in spring, on account of the distance of the Earth from the Sun being equal at those two periods, and the Sun's rays being received at the same degree of obliquity at any given spot,—yet the autumn heat is increased by the accumulated heat of the summer. The surface of the Earth receives in summer so large a portion of heat, that a considerable time elapses before it can be radiated upwards into the air, and thus is formed a magazine of heat, by which the autumnal warmth of the Sun's direct rays is augmented; and hence we are furnished with the fructifying temperature so propitious for the time of harvest.

From the 21st of September, the Earth progresses towards the north-wintry position, on the right, which she attains about the 24th of December. Here we find a marked change in the relative position of the north and south poles: the north pole is turned away from the Sun, while the south pole inclines towards him. Hence, the north pole and all the adjacent parts, including, in fact, the whole northern hemisphere, receive a much smaller share of the Sun's heat than is enjoyed by the southern hemisphere; and thence come the northern winter and the southern summer. The inhabitants of the northern hemisphere strive to compensate for the deficiency of the Sun's heat by additional clothing and additional contrivances for procuring artificial warmth in their dwellings, while the inhabitants of the south luxuriate in the overarching light and heat of the Sun. Our emigrant countrymen in New South Wales and Van

Dieman's Land experience the joys of summer at the time when we are striving to exclude from our hearths the chilling blasts of winter. If a vessel be six months performing the voyage from England to Australia, and leave England in the middle of summer, it reaches Australia also in the middle of summer; that is, it would have a northern summer at the commencement of the voyage in June, and a southern summer at the termination of the voyage in December: the vessel follows the *declination* of the Sun in the seasons; that is, its diminishing and increasing distance from the equator. When the vessel set sail, the Sun was vertical considerably to the north of the equator: as the vessel crossed the line, the Sun was vertical thereabouts at the same time: and when the vessel arrives at its destination, the Sun has arrived at its greatest southern distance from the equator.

Such is the effect which the obliquity of the Earth's axis produces on the succession of seasons: if that axis were perpendicular to the plane of the Earth's orbit, or, which amounts to the same thing, if there were always some part of the equator precisely between the centres of the Sun and the Earth, we should have no vicissitudes of seasons, because the Sun would be always at an equal distance from both poles.

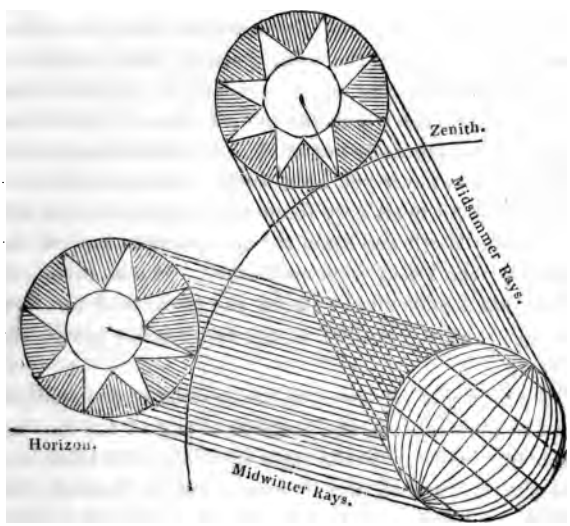
We have already stated that the Sun is nearer to the Earth in the winter than in the summer; and it would seem that the Earth should receive a larger portion of heat in December than in June; but the obliquity of the Earth's axis, which gives rise to the phenomena of seasons, almost altogether obviates the mere effect of propinquity. The consequence of this obliquity is, that in the middle of summer, the Sun attains an *altitude*, or

elevation, above the horizon, of sixty-two degrees; while in the middle of winter, he does not reach higher than fifteen degrees, in the latitude of London. This difference of meridian-altitude is due to the greater or less distance of the spot where the Sun is vertical, from the parallel of latitude in which London is situated: and as the Sun passes round our globe every twenty-four hours, it is constantly describing a winding course from one tropic to the other. It is this *spiral* or winding motion, which the poet Thomson alludes to in our quotation at the head of this chapter. Now the simple circumstance of the summer altitude of the Sun increases the amount of heat received, in two different ways; first, the direct rays of the Sun have more power at a high, than at a low elevation, because they have a less thickness of atmosphere to pass through; second, a longer time must be employed by the Sun in attaining a great altitude above the horizon, than in attaining a smaller altitude: so that he must then be above the horizon a greater number of hours during the day, and consequently shed a larger amount of light and heat in the case of the greater altitude than of the smaller. These are occurrences with which we are familiar from year to year, because they exert too extensive an influence on the affairs of life to escape our notice. If, however, we compare these occurrences with the different positions of the Earth, as represented in the foregoing figure, we shall see that the whole depends upon whether the northern hemisphere in which we live, is turned nearer to, or farther from, the Sun, than the southern hemisphere.

But we cannot help noticing that, as the southern hemisphere has its summer while we have our winter,

although we may not feel our winter to be much mitigated by greater propinquity to the Sun at that season, it would follow that the southern summer should be warmer and the winter colder than with us; and the testimony, if we may rely upon it, of those who have tried the experiment in both regions of the world, corroborates the inference which science had previously drawn.

Fig. 23.



SUMMER AND WINTER ALTITUDES OF THE SUN IN THE LATITUDE OF LONDON.

Now, in order to estimate the real position of the Earth in space at any given time, or the apparent position of the Sun, the astronomers of old time devised a method, which is still in use, and which we now proceed to detail.

The myriads of stars with which the heavens are studded, and whose glittering brilliancy forms such a sublime object of contemplation in our long winter nights, we call for the most part *fixed;* as we find them maintain constant distances and positions with regard to one another: this circumstance gives them a value as standards, by which we may compare the motions of other bodies. If we use a twelve-inch rule to measure the distance between two points, the value of the rule depends upon the circumstance that the inches are always exactly the same distance apart; and so it would be with any other standard of measurement. When we consider that the Sun, immensely distant as he is, is yet infinitely nearer than the fixed stars, whose distance has never yet been ascertained, we shall perceive that he must very frequently appear to come between the Earth and some one star, so as to conceal the star and the Earth from each other. It has, therefore, been found convenient to refer the position of the Sun to that star, the position of the latter being previously known.

By this plan astronomers can describe to one another and to their readers, the positions of any of the moving heavenly bodies. In the early ages, when the Chaldean shepherds watched the heavenly bodies through the clear and serene atmosphere of Syria and Mesopotamia, and at a later period when the Arabians cultivated astronomy, the stars were parcelled out according to some fancied resemblances to animals and other objects, as may be seen on a celestial globe. In many instances it baffles both the eye and the imagination of a modern observer, to detect any resemblance to the objects named in this celestial menagerie; but in so far as it enables

us to map out the stars into convenient and small portions, the arrangement is of service. Each of these sets of stars is called a *constellation*, or assemblage of stars. It is to this plan of comparing the clusters of stars to the forms of certain animals and other objects, and the practice of representing them on our globes, hat Darwin alludes in the following lines:—

So erst, 'ere rose the science to record
In lettered syllables the volant word;
Whence chemic arts, disclosed in pictured lines,
Lived to mankind by hieroglyphic signs;
And clustering stars, portrayed on mimic spheres,
Assumed the forms of lions, bulls, and bears.

In the course of the circuit which the Sun appears o make among the stars in a year, (*see Frontispiece,*) he ancients managed to trace out resemblances to welve objects in particular, each object being repreented by a cluster of stars, through the midst of which he Sun had to pass. The Latin and English names, nd the symbols by which these are known, are the folowing:—

Aries	the Ram	♈
Taurus	the Bull	♉
Gemini	the Twins	♊
Cancer	the Crab	♋
Leo	the Lion	♌
Virgo	the Virgin	♍
Libra	the Balance	♎
Scorpio	the Scorpion	♏
Sagittarius	the Archer	♐
Capricornus	the Goat	♑
Aquarius	the Waterman	♒
Pisces	the Fishes	♓

These twelve are called the *signs of the Zodiac;* this latter term being derived from the Greek for an *animal.* The remaining constellations, north and south of the the Zodiac, amount to eighty-two.

Now, when the Sun is said to be in Aries, for instance, it means that he is situated between the Earth and that cluster of stars, which is named after the *Ram;* and so accordingly with any other cluster of stars. When these names were first given to the different sets of stars, the Sun, on the 21st of March, was about coming between the Earth and the sign Aries, or Ram, and that position was called the *first point of Aries:* for a long series of years, therefore, the Sun arrived at the first point of Aries on the 21st of March. In order now to obtain precision in naming the position of the Sun at any other period, the whole apparent circle described by him was divided into twelve equal parts; whether or not these parts exactly coincided with the outlines of the clusters of stars from which they were named. Each of these portions, or signs, was further divided into thirty equal parts, called *degrees;* so that the position of the Sun at any period could be expressed with great accuracy. This apparent motion of the Sun is from west to east,—or from the sign Aries to Pisces,—and results from the motion of the Earth in the same direction.

In the course of ages, however, it was found that the Sun did not occupy the same position in the constellation Aries on the 21st of March, as he had occupied at an earlier period. This is occasioned, not by a motion of the stars, but by a change in the point of the Earth's orbit at which the two hemispheres are equally exposed to the Sun: a point, which is generally expressed as

that in which the plane of the equator cuts the plane of the ecliptic. This point is called the *equinox*, from the circumstance that the day and night are equal to all parts of the world, when the Sun is at the point of intersection. This motion of the equinox is called the *precession of the equinoxes;* or more properly the *recession*, because they appear to travel *backwards*, and the signs *forwards:* it is occasioned by the attraction of the Sun and Moon for the mass of terrestrial matter at the equator. This precession is, however, so exceedingly slow, that it has taken about two thousand years for the equinoctial points to recede through one sign, or 30°, from the point where it was fixed by Hipparchus, who was called the "father of astronomy." The vernal equinox, on the 21st of March, now occurs when the Sun is actually in the constellation Pisces; but still, for the convenience of maintaining the same nomenclature, the Sun is *said* to enter the first point of Aries on the 21st of March: it therefore results that the *sign* Aries does not correspond with the *constellation* Aries.

We now understand what is meant by the tropic of Cancer, and the tropic of Capricorn; and we shall also see in what way the signs of the Zodiac become symbols, as it were, of the kind of season which we experience, by merely considering that the Sun is between us and those constellations. For instance, when spring is about verging towards summer, the effect is thus alluded to:—

> At last from Aries rolls the bounteous Sun,
> And the bright Bull receives him. Then no more
> Th' expansive atmosphere is cramped with cold;
> But, full of life, and vivifying soul,
> Lifts *the light clouds* sublime, and spreads them thin,
> *Fleecy and white,* o'er all-surrounding Heaven.

In the middle of a northern summer, the Sun is in the sign Cancer, and at that time the inhabitants of that portion of the Earth where the tropic of Cancer is situated, have the noon-day Sun precisely over their heads; that tropic being the most northern situation in which such a circumstance occurs. From thence the Sun gradually travels in a spiral manner down towards Capricorn, during which time Autumn's milder heat succeeds to Summer's glow,—

When the bright Virgin gives the beauteous days,
And Libra weighs in equal scales the year;
From Heaven's high cope the fierce effulgence shook
Of parting summer, a serener blue,
With golden light enlivened, wide invests
The happy world. Attempered suns arise,
Sweet-beamed, and shedding oft through lucid clouds
A pleasing calm; while broad, and brown, below
Extensive harvests hang the heavy head.

Again, when the Sun is in the sign Capricorn, the inhabitants of the line called the tropic of Capricorn have their noon-day Sun vertical. For ourselves and the northern hemisphere, it may be remarked that at this season, when

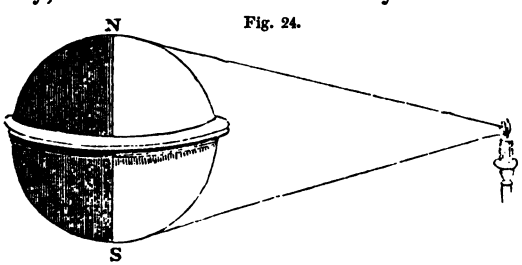
. . . . . the cheerless empire of the sky
To Capricorn the Centaur Archer yields,
And fierce Aquarius stains th' inverted year;
Hung o'er the farthest verge of Heaven, the Sun
Scarce spreads through ether the dejected day.
Faint are his gleams, and ineffectual shoot
His straggling rays, in horizontal lines,
Through the thick air; as clothed in cloudy storm,
Weak, wan, and broad, he skirts the southern sky;
And, soon descending to the long dark night,
Wide-shading all, the prostrate world resigns.

If, in astronomical works or almanacs, the reader should meet with such expressions as "the Moon is in Aries," or "a conjunction will take place in Libra," &c., he will at once understand that he must look for this event in the cluster of stars forming such a constellation, although he may feel quite certain that the Sun, or Moon, or planets, are much nearer to him than the constellations to which he refers them as a background, and to which they seem, at the time, to belong.

Day and Night.

We will now explain the causes of the different amount of *light* which we receive at different hours of the day, and at different seasons of the year.

Fig. 24.



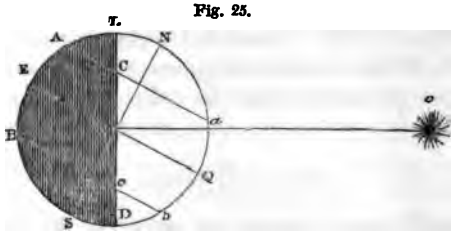
The Sun is the great source of light to the solar system; and without him, all would be dark and invisible: we must therefore direct our special attention to the position of the Sun, in order to understand the changes from light to darkness.

The question of day and night depends upon this principle, that one-half of a globe, and no more, is illuminated by one source of light, as we see in the figure above. If the candle is placed in the plane of the *equator, for instance*, then, as the globe is turned

round, one hemisphere is constantly illuminated from north to south.

But now suppose we have a miniature representation of the Earth, and suppose the Sun at *o* to be shining

Fig. 25.



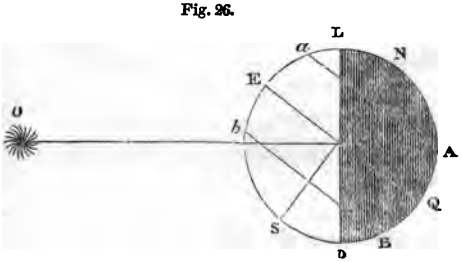
SUMMER SOLSTICE.

on the parts at *a* from some distance on the right. We then find one-half of the globe illuminated, and the other half shrouded in darkness. If N S be the axis of the globe, round which it may be supposed to revolve, then E Q is the equator, B *a* the ecliptic, and A *a*, B *b*, the two tropics. The line L D separates the dark from the illuminated hemisphere, and is therefore the *real* horizon. Let the spot *a* represent any given place, and let us see what will occur if the globe revolve on its axis N S. In its present position, the spot *a* receives a large and continuous amount of light from the Sun; because he is not invisible until *a* arrives at the position C: when, however, the globe has turned half round on its axis, we find the place in question at A, where it is shrouded in darkness. These effects, it will be perceived, are brought about by the motion of the globe on its axis. Furthermore, we see that the North Pole has constant day, and the South Pole constant night; for, as the globe revolves upon N S, L N must always be in the light, and S D in the shade. Again, suppose the

ree lines, A *a*, E Q, B *b*, to be the parallels of latitude certain places; at A, E, and B, it is midnight,—at C, the centre, and at *c*, it is sunrise; and at *a*, Q, and *b*, is mid-day. As our figure represents the time of the nmer solstice*, we see that, at the North Pole, there no night; at the tropic of Cancer, there is a short ght and long day; at the equator, the day and night equal, as is always the case; at the tropic of Capri- n the night is long, and the day short, and at the ıth Pole there is continual night.

We will now take the case of the winter solstice, ıen the former positions will be reversed, as we see the accompanying figure. The globe, which is illu-

Fig. 26.



WINTER SOLSTICE.

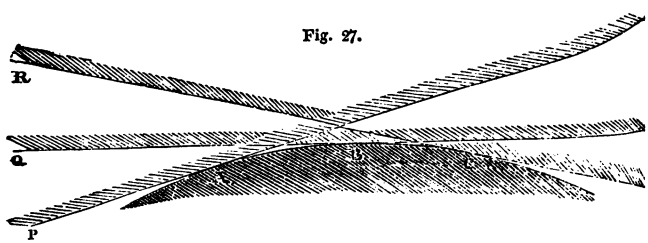
ıated as to one hemisphere by the Sun at O, revolves its axis N S, so that L N is constantly in the dark, l S D constantly in the light. The places on the thern parallel *a* A, have a short day and long night; E Q they have the day and night equal; and at the

The term *solstice* is from the Latin, and denotes the *ding still of the Sun;* because, at the times of the solstices, Sun does not change its declination for several days toge-

southern parallel *b* B, a long day and a short night; at s there is constant day. At the equinoxes, the real horizon passes through the poles.

Now, the surface of the Earth, to a spectator standing on it, does not seem to form part of a globe, because the curvature is so very gradual: it seems to be a flat surface, the *boundary* of which is called the *visible horizon:* it follows, therefore, that every different spot on the Earth's surface has a different horizon. When, therefore, we speak of sunrise, we mean that the Sun first makes his appearance above the horizon of the place we are in. If, then, each separate place has a different horizon, it follows that the absolute time of

Fig. 27.



sunrise is different at the different places. In the above figure, A B C is a segment of the Earth's surface. The horizon of A is in the direction P A; that of B in the direction Q B; and that of C in the direction C R. Now, if we imagine the Sun rising on the left hand, it is evident, by inspection, that the people at A must see him when he shall have arrived at P; that the inhabitants at B must wait till he shall have arrived up at Q; and that the people at C will only begin to see him at R; or, more strictly speaking, the Earth revolves in the direction C B A, and so the horizon of each place rolls towards the Sun.

Refraction.

From what has been stated, and from the circumstance that the Sun is the source of light to the Earth, it would seem that the moment the Sun set, or became concealed from us, we should at once be immersed in darkness; a transition so sudden, that the presence of the stars, or even of the Moon, would not be sufficient to recompense us for the deprivation of the Sun's light. All this would occur, if there were no atmosphere surrounding the Earth. The atmosphere, which supplies us with the means of respiration, and with a medium for the communication of sound, which supports combustion, which is an aërial ocean in which birds can float,—this same atmosphere, wrapped round us like an invisible garment, serves to soften the intensity of the noon-day heat of the Sun, to give him his ruddy colour at rising and setting, and also to furnish us with that subdued light which, under the name of *twilight*, moderates the change from light to darkness, and prepares us by degrees for the still, cold, calmness of night. We must explain how this occurs.

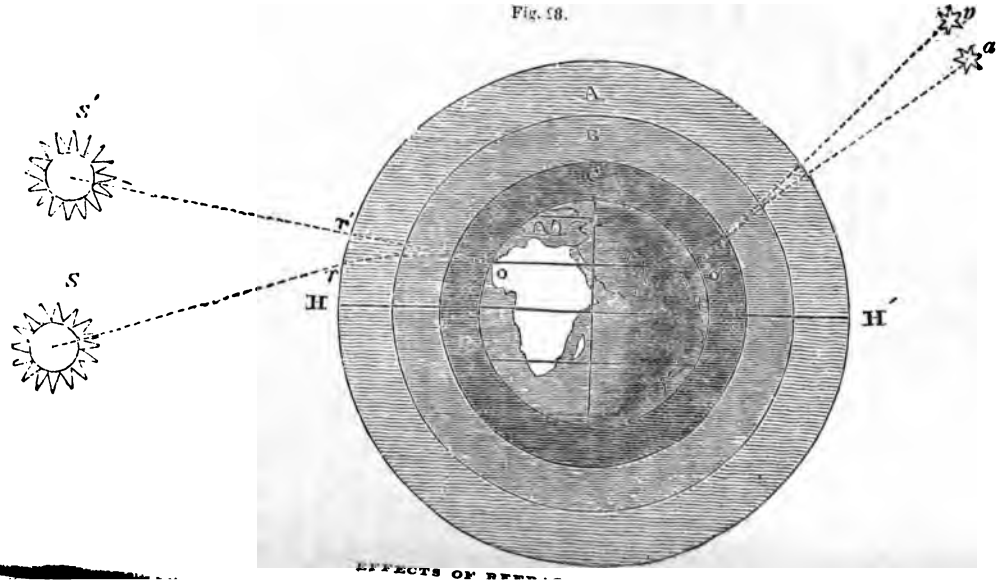
When a ray of light is passing through a transparent body, it moves in a straight line, so long as the medium remains of the same density; but if any change occur in the density, or compactness, of this medium, the rays become bent out of the straight line, the bending taking place towards the denser portion: this bending is called *refraction*. Now, the atmosphere which surrounds the Earth consists of a light elastic fluid, not $\frac{1}{800}$th part so heavy as water; so that the upper portions press on those which are lower, and make them more dense or compact than they otherwise would be:

this compression gives to the lower portions of the atmosphere a power of refracting rays of light more than the upper portions.

The atmospheric air, then, is most dense at the surface of the Earth; and its refractive power gradually decreases, until we get to a density of air so small, that it ceases to disturb the direct progress of a ray of light. When a ray falls upon a medium of varying density, such as the air, it will be turned gradually out of its path so as to form a curved line, as shown in the figure, where we have the Earth surrounded by an atmosphere of varying density, the density at C being greatest, and least at A. Now, if H H′ be the horizon of an observer, and S be the Sun actually below his horizon, the ray *s r* will proceed in a right line until it meets with the atmosphere A, when it will begin to turn out of its previous path; and were the refracting medium of the same density throughout, the new path of the ray would be in a right line also; but not in the same direction as the first. But, as we have seen that the density of the refracting medium increases as we approach the Earth, the ray is consequently more and more refracted on entering the strata at B and C, so that an observer at O receives this refracted ray in a curved line; but, as he can only see an object in straight lines, it follows that he seems to receive the Sun's rays at *r*′, and that an image of the Sun is seen by him at *s*′.

Hence it is inferred that the heavenly bodies are never seen in their true places, except when in the zenith; refraction having no effect on a vertical ray. Refraction is greatest at the horizon, and decreases upwards, as may be noticed in the case of the star *a*, *which is* seen at *a*′ by an observer at O; but, being

Fig. 18.



igher up, its rays are not so much refracted as in the case
the Sun. The altitude of the heavenly bodies seems
reater, therefore, than it really is, in proportion as we
me down to the horizon, where the air is thicker
id more humid. The effects of refraction were first
ticed by Ptolemy, the Egyptian astronomer, about
ie year A.D. 140.

While the Sun is within 18° of the horizon, or for
a hour and twelve minutes before sunrise and after
nset, we have some light from the Sun; and for
any nights about the time of the Summer solstice,
ie Sun being within 18° of the horizon, we have no
ctual night.

It follows, therefore, curiously as it may seem, that,
hen we seem to see the Sun just above the horizon at
nrise and sunset, he is not actually above the horizon,
ut only seems so, in consequence of the bending round
his rays towards the parts where we may be*.
gain, the thickness of the stratum of horizontal air
akes the Sun and Moon appear larger than when
eir rays come down to us less obliquely; and, owing
the difference of the density of the air at the upper
id lower parts of the disks of the Sun and Moon,
ese bodies are often seen of a compressed or oval
rm.

* It was in consequence of this effect of refraction that on
e 20th of April, 1837, the Moon appeared to rise eclipsed,
fore the Sun had set: which, but for refraction, could not
ssibly have happened; for the three bodies would not have
en *in a line.*

CHAPTER VIII.

THE TIDES. GENERAL THEORY OF TIDES. SPRING AND NEAP TIDES. AERIAL TIDES. LATITUDE AND LONGITUDE.

Tides.

We must now recur to the consideration of the *direct* influence of the Moon upon our globe, and give our attention to the third class of phenomena which we enumerated at page 114, as resulting from the joint operation of the Sun, Moon, and Earth—the TIDES.

In our second chapter, we stated that one of the properties of matter is to attract other matter towards itself: for example, that a stone drops to the Earth, by virtue of the Earth attracting the stone; that the planets retain their wonted distances from one another, and from the Sun, by virtue partly of the operation of this law.

Now it will not be difficult to conceive that, if attraction has reference to all matter, and if the Earth and Moon attract each other reciprocally, the Moon's attraction, if not felt to influence the *solid* matter of the Earth, may produce a great effect on that form of matter which is most easily moved, *i.e.*, the *liquid* form. Now, if we exert an attractive or moving power of any kind, on a solid mass, such as of iron, the whole mass will be moved at once, if any part be moved; because *the particles* of which it is composed are so closely and *intimately* bound together, that a pressing or pulling

force will not separate them; unless, indeed, it be very enormous. With a liquid, however, we know that such is not the case. If we move the finger rapidly to and fro in a basin full of water, we shall separate some of the water from the remainder, and propel it over the edge of the basin: we can dip a vessel into the water, and take out a portion of it, without altering the nature or appearance of that which remains. A solid body may be immersed in the liquid, so as to be completely surrounded by it; thus showing the ease with which the bulk of water may be separated, so as to allow other bodies to insinuate themselves between its particles. Nothing of this kind happens with *solid* bodies; and this difference is the sole cause of the production of Tides, which we proceed to explain.

The reason why the Earth revolves round the Sun, instead of round any of the planets, is, that the large mass of the Sun exerts a stronger attraction than any of the planets. Again, the reason why the Moon revolves round the Earth, is, that she is much nearer to the Earth than to any other planet; while at the same time she is much smaller than the Earth.

The distance between the Earth and the Moon is regulated by the amount of the attraction of one for the other, and by the velocity of the Moon's motion; and as those quantities are equal year after year, there is no perceptible disturbance exerted by one on the other. This is, however, only true with reference to the Earth, considered as a *whole:* we must bear in mind that three-fourths of her surface is covered with water, a substance more likely to be influenced by an attractive force than a solid body, owing to the ease with which the particles of water glide over one

another. It is found that, although the Moon's a tion of the Earth, as a whole, is neutralized b counteracting attraction of the Earth for the M yet the waters on the surface of the Earth, ha loosely together as it were, suffer a perceptible nation towards that quarter where the Moon m situated.

Let us suppose, while discussing the Theory o Tides, that the *whole* of the exterior of the Earth sists of water. This will make our illustrations cl We will also first suppose that there is no Moon t on this watery surface of the Earth; then the w would maintain their wonted level, which we represent by the shaded ring *a b* surrounding the Ea (No. 1, fig. 29.) But suppose now (No. 2) the M M, to exert her influence on the surface of the E then we must suppose that the waters on the Ea surface would flow towards the side *b* of the E nearest to the Moon, in consequence of her attra of them, and that they would thus be drawn up in protuberance, by which an additional quantity of w would be collected on the side *b*, which could only c by a deprivation of the proper quantity elsewhere, w is indicated by the diminution of the width of aqueous ring at the other parts, and chiefly at *a*.

Fig. 29.

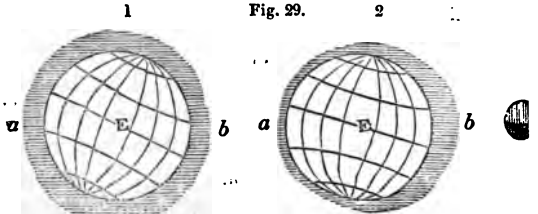
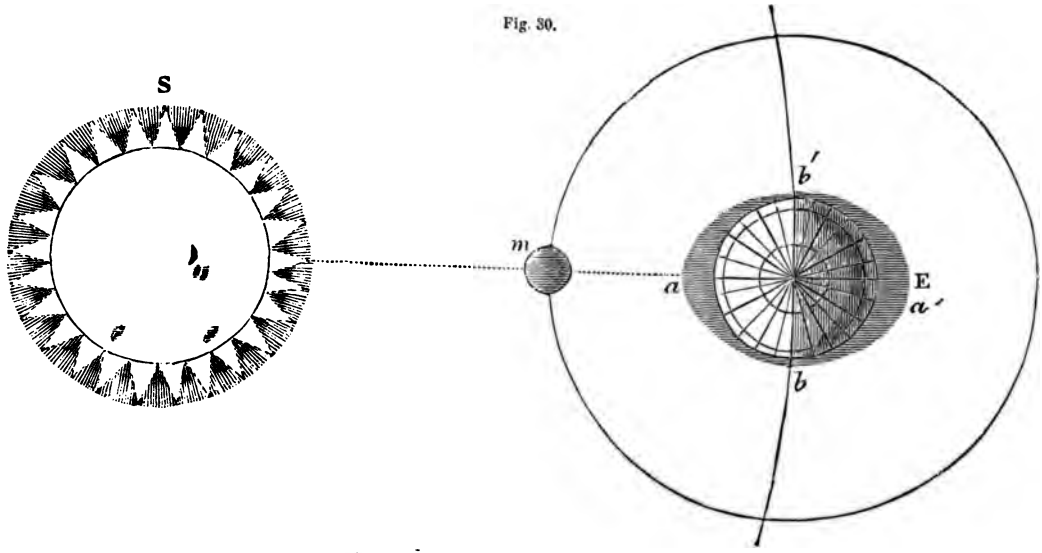


Fig. 30.



SPRING TIDE AT THE NEW MOON.

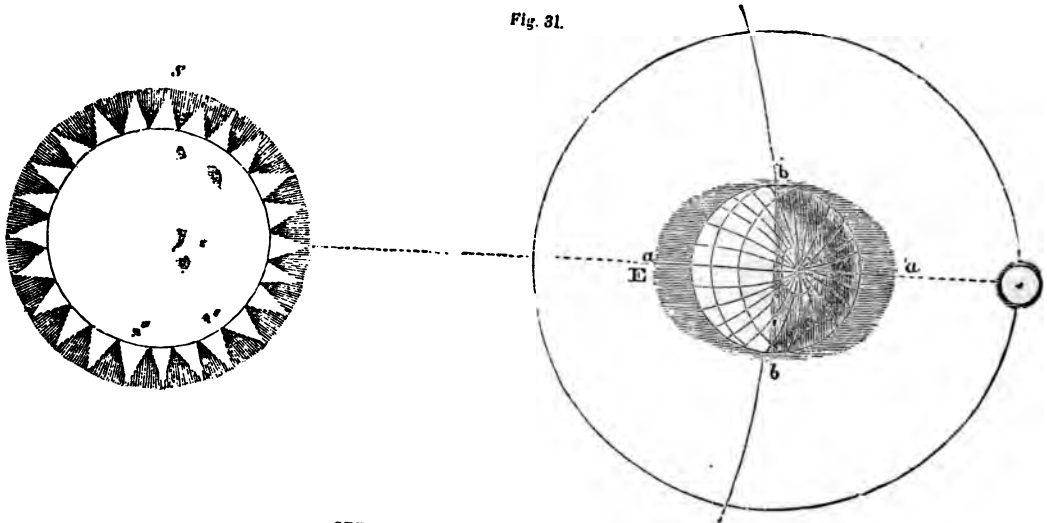
But here, against all this, we have a remarkable circumstance to notice. We actually find in nature that not only is the water nearest to the Moon drawn towards it in the way just described, and is therefore elevated, but the water on the *opposite* side of the Moon is elevated in like manner. Now it is plain that the Earth itself, the solid part (especially in a central direction), must feel the attractive or *drawing* influence of the Moon in a greater degree than the portion of water which is most remote from the Moon. The real form of the liquid surface therefore becomes something like that of an egg, the small ends being formed by the protuberant water at each extremity, and the flattened sides being due to the diminution of the quantity of liquid which would otherwise belong to them: the real nature of this rise of the waters is therefore better represented by the accompanying figures, where it will be seen the waters are collected in greatest quantity at the sides nearest to, and furthest from, the Moon, that is, at the *zenith* and *nadir*. In fig. 30 the Moon is new, or in conjunction; in fig. 31 the Moon is full, or in opposition. Hence the same effects are produced *twice* in the lunar month—at *new* and *full* moon.

We have hitherto considered the action of the Moon only on the waters of the Earth; we must now refer to that of the Sun. Although the Sun is so much larger than the Moon, yet his distance exceeds that of the Moon in a still greater ratio; so that his specific attraction for the waters of the Earth is less than that of the Moon; the attractive force of the Sun being to that of the Moon (as is generally considered) 1 to 5. We have therefore to add, or to subtract, the Sun's attraction, according as it assists or opposes that of the

Moon. Suppose (fig. 32) that the Moon is in *quadrature;* that is, in the first or last quarter. In this state, as before explained, the Sun S, the Earth E, and the Moon *m*, form a right-angled triangle. The Sun acts on a part of the Earth *b*, which is a quarter of a circle removed from the spot *a*, on which the Moon acts. In fact, the Sun acts precisely on the part depressed through the Moon's action. As the Moon, therefore, would cause the waters to rise at the two parts *a* and *a'* in the proportion of 5, while the Sun's influence at *b* and *b'* is in the proportion of 1, we have by these means four protuberances instead of two. We have represented these as separated by indentations, for the sake of clearer illustration. Hence by subtracting the Sun's effect 1 from the Moon's effect 5, we have remaining 4, which expresses the highest tide in this position of them.

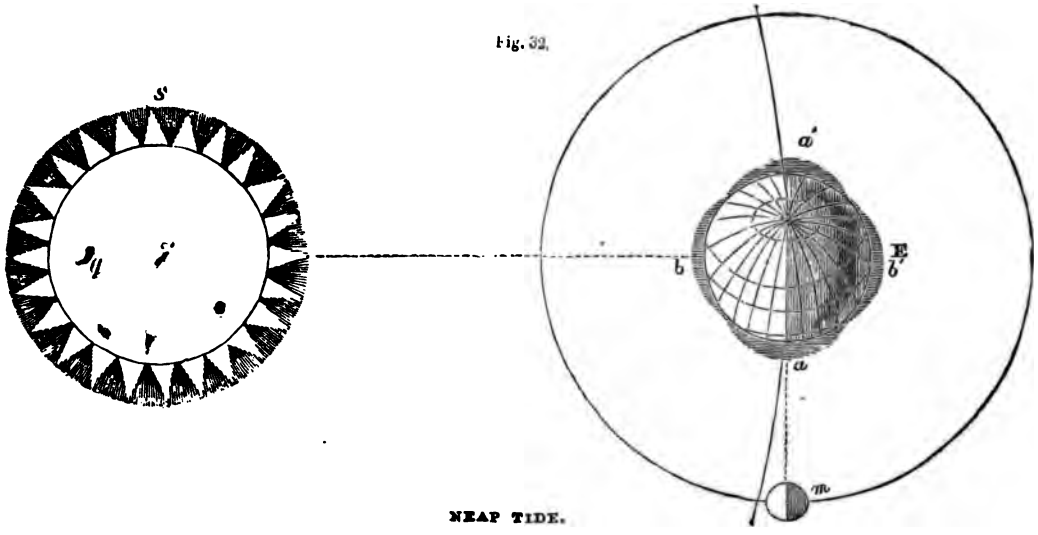
But now suppose again that the Moon is either *full* or *new:* the three bodies in question are then in a line, and the action of both Sun and Moon will be concentrated to the same points, and the rise will be greater than if the Sun had not been present. It matters but little whether the Moon be new, as at *m*, fig. 30, or full, as at *m*, fig. 31; because in either case the effect is to raise the waters at *a a'*, and to depress them at *b b';* for the attractive force of the two bodies, when the Moon is new, operates most at *a*, and least at *a'*—partially at *b* and *b'*. In the sinking down of the water at *b* and *b'*, the greater portion is carried off towards *a*, and a smaller portion goes round to help to raise the parts at *a'*, where the water is least affected by the attracting bodies. The like reasoning may be used in reference to the full Moon (fig 31), where the rise at *a* and *a'* is followed by the subsidence at *b* and *b'*.

Fig. 31.



SPRING TIDE AT THE FULL MOON.

Fig. 32.



NEAP TIDE.

It should, however, be observed in addition, that the curious circumstance of high water at the zenith and nadir at the same time, has been accounted for by reference to the centrifugal force of the water of the Earth; which force is generated by the rotation of the Earth on its axis, and is greatest at the contrary side of the Earth to the Moon: so that high water at the side nearest to the Moon is due to her positive attraction; but on the side furthest from the Moon to uninterrupted centrifugal force.

These fluctuations of the waters of the ocean constitute TIDES. As the Earth revolves on its axis the protuberant waters travel in the opposite direction, being chiefly influenced by the Moon; and to a certain extent by the Sun. The Moon comes to the south of us every day later than on the preceding day, and the time of flux or high tide at any place is also later every day than on the preceding, in the same proportion; which is a sufficient indication of the superior attraction of the Moon. As there are two opposite protuberances, or high tides, on the surface of the Earth at one time, it follows that, in its turning once on its axis, every part of the Earth experiences two high tides and two low tides intermediate between them. These alternations in the open sea are at intervals of about six hours asunder; but in rivers great irregularities occur; where, very generally, owing to the impediments of the banks, the tide rises higher than in the open seas. In order to supply the additional quantity of water to those two portions of the Earth which are in a line with the centres of the Moon and Earth, the rivers and seas on each side must part with a portion of their waters, which is returned to them about six hours

afterwards; but this flux and reflux, or ebb and flow, is much retarded by the nature of the channels through which the water has to flow; so that high tides occur at very various times in parts of the world not much distant from each other.

If the Moon were stationary, an ebb and flow would occur every twelve hours; but, as the Moon revolves round the Earth, the Earth must make rather more than one revolution on her axis, before two ebbs and two flows can be completed: hence, high water is about three-quarters of an hour later on each succeeding day. The tides at new and full Moon, which are greater than those when the Moon is in quadrature, are called *spring* tides, and the latter *neap* tides. The tides suffer a variation in amount from another cause. We have seen that the Moon revolves in an elliptical orbit; so that at one time she is nearer to the Earth than at another time. Now if the spring tide happen when the Moon is at her shortest distance from the Earth, the tide will be greater from that cause also than if she were more remote; and if at the same time the Earth be at its nearest distance from the Sun at the time of spring tide, the tide will then be the *greatest* that can occur.

It is not, however, high water at the parts *immediately under* the Moon: the attraction of the Moon takes time to produce its full effect; so that three hours elapse, even in the open ocean, before the completion of the highest tide: that is, if the Moon came over any given spot at twelve o'clock, it would not be high water there until three. An analogous circumstance is observed in the hottest month of the year, and the hottest hour of the day. The Sun sheds most heat on our portion of the Earth in June; yet we find July and

August to be hotter: again, he sheds more heat at twelve o'clock than at any other hour; yet we find one and two o'clock to be hotter. This arises from the fact that the Sun's influence is felt as if it were *accumulated*, after his greatest direct effect is passed, by reason that the Earth is *already* saturated with heat. In like manner, the spring tide is not until about three days after new, or full moon; and the greatest spring tide not until February and October. The Moon's effect is felt, in fact, after it has ceased to operate, on the principle in Mechanics, that the effect of a force continues even after the motive power has subsided.

When the Moon is above the horizon more than twelve hours in one day, one of the tides is higher at that place than the other on that day, because the Moon is acting upon that spot for a longer period: but if the Moon be above and below the horizon for about equal periods, the two tides are also about equal. The tides are very unequal at different places, chiefly on account of the nature of the channel in which the water is confined. At Plymouth the difference between the highest and lowest tide, on the same day, is sometimes twenty-one feet; while at Mount St. Michael, in Cornwall, it is sometimes eighty or ninety feet.

In perusing the history of Ancient Navigation, we find that the ancients, whose naval pursuits were long limited to the Mediterranean Sea, were ignorant of tides; this sea, as likewise the Baltic, not being apparently so affected by the solar and lunar influence, as to exhibit an ebbing and flowing of their waters. These seas have inlets so narrow, as not to allow of a free passage of the water; and the attractive influence has passed away before any very sensible effect is produced. In

the case of these seas, and also of lakes, the Moon's influence is equally exerted; and, there being no swell, is less perceptible. Though we learn that the cause of the tides was first suspected by Pytheas, a navigator, who flourished 400 B. C., yet Newton was the first to demonstrate that the tides were the result of the attraction of the Sun and Moon; and thus did he add another to the long list of benefits which he conferred on posterity, by explaining those sublime and beautiful laws, according to which it has been ordained that the world shall be governed, by Him who—

> Gives and guides the Sun's attractive force,
> And steers the planets in their silver course;
> With heat and light revives the golden day,
> And breathes his spirit on organic clay;
> With hand unseen directs the general cause,
> By firm, immutable, immortal laws.

Air, being lighter than water, and being likewise nearer to the Moon, must be more within her influence: hence there are doubtless aërial tides; of which if the nature were well understood, the subject of meteorology and of the *weather* generally, would be more decidedly a *science* than it now is.

Latitude and Longitude.

The ancients knew that a great boundary to the west was formed by the Atlantic Ocean; but the confines of the Earth towards the east they supposed were illimitable. Hence, the distance on the Earth's surface, measured from west to east, they termed *Longitude*, or measurement in length, which they supposed infinitely greater than the measurement in breadth, north and south, which they termed *Latitude*. Ptolemy, in the

middle of the second century of the Christian era, first used this mode of fixing the positions of places on the Earth's surface.

In the modern acceptation of the terms, *latitude* is the distance of any place north or south from the equator; and *longitude*, its distance east or west of any given meridian. Thus, the line of latitude is always at right angles to the line of longitude; and the spot, denoted by a certain latitude and longitude, is situated where these lines cross each other. This mode of marking out the position of a place on the surface of the Earth, is referrible to the motion of the Earth on its axis: which motion is the most constant and equable in nature.

Fig. 33.

In the subjoined figure, we have a representation of the terrestrial globe. The North and South Poles, P and Q, are the extremities of the imaginary axis; or

those points which do not revolve at all. The equator, E M B R, is equi-distant from these points. Lines parallel to the equator are called *parallels of latitude;* of which as many may be drawn as we choose; but it is usual in maps and globes to draw them through every 10° northward and southward: the space between every two parallels being then divided into ten parts, each of which is a *degree.* From P or Q to E or R are reckoned 90°, which is one quadrant of the globe.

It is usual for the principal nations in the world, which have cultivated science, and made themselves respectable in the opinion of fellow-nations, to reckon their longitude from the meridian of their own capital. Thus, the English reckon longitude from the meridian of Greenwich, which is, as it were, part of London, and is the site of the royal observatory. The French count degrees of longitude from the meridian of Paris.

Longitude is reckoned eastward and westward; and the meridians are usually drawn on globes and maps 15° apart, because the Sun passes over this extent of the Earth's surface in one hour; or all round the globe in twenty-four hours: so that there are twenty-four meridians, or *lines of longitude,* such as we see drawn from P to Q, where the line P A Q is the meridian of A. Each degree of longitude is, at the equator, about sixty-nine and a-half English miles; and each degree becomes less as we recede from the equator towards the poles, in consequence of the circles getting smaller.

CHAPTER IX.

THE EXTERIOR PLANETS. MOTIONS OF THE PLANETS—STATIONARY, DIRECT, AND RETROGRADE. MARS. THE ASTEROIDS. JUPITER—MOONS OF—THEIR USE IN FINDING THE LONGITUDE AND IN DETERMINING THE VELOCITY OF LIGHT. SATURN—RING AND MOONS OF. URANUS—MOONS OF.

In making observations upon the heavens, and the globes which exist and move about in them, the beholder, whether ordinary or telescopic, has his attention arrested at one time by the apparent size,—at another time by the brightness,—then again by the colour,—then by the sparkling,—then by the steady light of the celestial object of his vision:—these circumstances, one or more, are found to apply to the planets spoken of in chapter 5, and likewise to the remaining planets, of which we are now about to speak. But most curious and singular above all, is the Ring of Saturn. To this nothing like or similar is found in the celestial creation; and so forcibly are we struck with this consideration, that, in passing beyond the orbit of the Earth, we have our mental vision directed to it at once, though in order, it is the last but one of the planets to be treated of.

It astonishes us that a star should be found at all thus encompassed, and still more does it astonish us that there should be but one star, as far as our ken has enabled us to judge, which has so elegant, but mysterious, an ornament. Its nature and uses are matters of speculation, and easily occur, as suggested by fancy, to

the mind of the reader of astronomy; but when the reader finds that there is a planet beyond Saturn, which not only has no ring, but even a smaller number of moons than Saturn, he will feel himself puzzled to account for this seeming discrepancy in the regulation of the planetary globes by the Author of good, unless he remember for a moment that full observations have not yet been made on the planet Herschel, or Uranus, owing to its immense distance, and the comparative imperfection of the instruments of man. To this we may append the consideration, that by means inscrutable to us the Almighty has, in all probability, compensated to other globes the deficiencies which their greater distance has occasioned them.

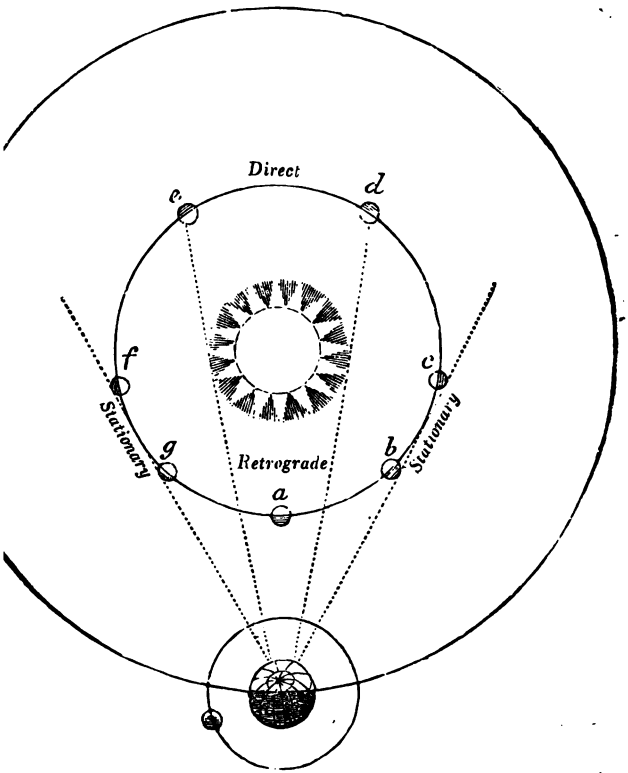
This consideration will apply likewise to the circumstance of no Moon being found to revolve round the planet Mars, which is further from the Sun than the Earth: but here, the constitution of its atmosphere is probably such, that so much solar light is absorbed and refracted, that lunar or reflected light is not found wanting. But we cannot afford to linger any longer in the regions of speculation; let us pass on therefore to consider

The Exterior Planets.

> Their wandering course, now high, now low, then hid,
> Progressive, retrograde, or standing still,
> In six thou seest.——Milton's *Par. Lost*, book viii.

Before we enter into the details of the planets, whose orbits are without that of the Earth, we have to notice a peculiarity in their motions as seen from the Earth, which results from the circular or elliptical form of their

Fig. 34.



MOTIONS OF THE PLANETS.

orbits, combined with the annual motion of the Earth. We have already alluded to this phenomenon in our second chapter, page 16.

When a planet appears to move from the neighbourhood of any fixed stars, towards others which lie to the east, its motion is called *direct*, because the planets move round the Sun from west to east. When a planet seems to move towards the stars which lie westward, its motion is said to be *retrograde;* and at other times it appears to be *stationary.*

Now as the planet is, in fact, constantly moving round the Sun, as its centre, it is said to have the three foregoing motions, which will be easily apprehended by the accompanying diagram (fig. 34).

Suppose a planet to revolve round the Sun from west by south to east, according to the letters *a*, *b*, *c*, &c. When the planet is so situated, that a line from the centre of the Earth will graze that part of the orbit where the planet is situated, the planet's motion is said to be *stationary*, as at *b c* and *f g*. The planet is then approaching to, or receding from, the Earth. When the planet is furthest from the Earth, it has its natural or *direct* motion, as from *d* to *e*. But when the planet is nearest to the Earth, as at *a*, its motion is termed *retrograde*, because, owing to the motion of the Earth in the same direction, it seems to go back in its course.

Mars.

See Mars, alone, runs his appointed race,
And measures out exact the destined space;
Nor nearer does he wind, nor further stray,
But finds the point whence first he rolled away.

This is the nearest planet which is exterior to the Earth, and is remarkable for having a more ruddy colour than most of the other planets. This ruddiness is believed to be due to a peculiar constitution of its atmosphere; whereby it absorbs all the component parts of the solar rays but the red, which it reflects.

The mean diameter of this planet is about 4189 miles, being rather more than half the diameter of the Earth. His form is that of an oblate spheroid, which is occasioned by his rotation on his axis, and is much more flattened than that of the Earth, his greater diameter being to his smaller as 16 to 15. He revolves round the Sun in an orbit which is, at the mean distance, about 144 millions of miles from the Sun: this orbit he travels round in about 687 of our days with a velocity of 53000 miles in an hour. We say *our* days, in order not to confound them with the day of Mars; for, as he rotates on his own axis in about 24 hours 39 minutes, his day is rather longer than ours, so that the period of his revolution is about 668 of his days. His rotation on his axis is estimated by permanent spots on his disk, which appear to be mountains as shown in figure 35.

There are some circumstances in the appearance of Mars which confirm the statement, that his orbit is exterior to that of the Earth. The appearance which *he commonly* presents is gibbous. This phase may be

illustrated by figure 36, A *a* B *b*. Here we see that A *a* B is a semicircle, and that A *b* B is part of an ellipse; these joined together form the *gibbous* phase. Thus Mars sometimes appears gibbous, (as shown in fig. 35,) but never crescent-formed; as he would be sometimes, if he revolved within the Earth's orbit: he appears nearly five times as large at one time as he does at another, on account of his being so much nearer to the Earth when the Earth is between Mars and the Sun, than when the Sun is between Mars and the Earth. When at his furthest distance from the Earth he subtends an angle of 4″, and when at his greatest distance an angle of 18″, and the inclination of his orbit to the plane of the ecliptic gives an angle of 1° 51′.

This planet is about one-seventh of the size of the Earth, and is supposed to enjoy about half the light and heat that we have, but in a similar proportion throughout his year, from the circumstance that his axis is inclined to the plane of the ecliptic, nearly at a like angle with the Earth's, though he is much further off from the Sun.

The matter, of which this planet is composed, is about one-fourth lighter than that of the Earth. His rotation on his axis, as determined by the motion of certain spots on his surface, is found out in the same way as has been already explained concerning the Sun.

No moon has ever been found to accompany this planet; though, being further from the Sun than the Earth, it would seem to stand more in need of a luminous auxiliary. But, by means of a good telescope, the poles, or extremities of the rotating parts of this planet, are observed to present a white appearance which becomes fainter when the pole, in the course of the

planet's orbital motion, is turned to the Sun, and decided when inclined away. These white sp naturally enough considered to be polar snows disappear at the parts of the planet which ha for some time exposed to the Sun, while in the time they reappear at the other part; the former the summer, the latter the winter, of Mars.

The axis of Mars makes with the axis of the an angle of about 30½°*. The Earth and Moon appear like moons to Mars; but, being in a between Mars and the Sun, would never appea full.

The Asteroids.

Until the present century, Jupiter was alwa sidered to be the planet next in order of dista Mars: but, since the commencement of this c four little planets called *Asteroids*, because th the *appearance of stars*, have been discovered, which are further from the Sun than Mars, b

* The term, frequently used in elementary works of nomy,—"inclination of an axis to the plane of an o is liable to mislead young readers from its ambiguity; a imply both the angle formed by the planet's axis with of its orbit, and that which is formed by the planet's a the *plane* of its orbit. Now, in the case of the Earth, mer would be an angle of 23½°, and the latter an angle The Earth has therefore a moderate diversity of seaso with the planet Venus, whose axis forms an angle of 7 the axis of her orbit, there is a very great diversity of s and none at all with Jupiter, whose axis is parallel w axis of his orbit; and scarcely any in the case of the which has its axis forming an angle of only 1½° with her orbit.

Fig. 35.

MARS IN THE GIBBOUS FORM.

Fig. 36.

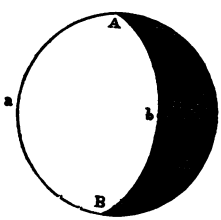
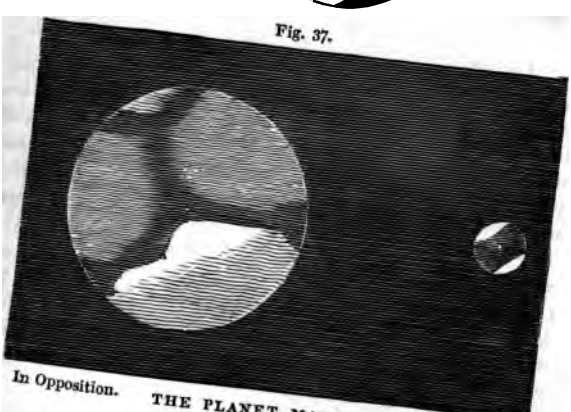


Fig. 37.



In Opposition. THE PLANET MARS. In Conjunction.

remote than Jupiter. These asteroids, or small planets, are called Vesta, Ceres, Pallas, and Juno, names of celebrated heathen deities of the feminine gender.

Vesta was discovered in 1807 by Dr. Olbers, an eminent German philosopher. It is supposed to be not more than 238 miles in diameter, though this is not yet considered as settled: its mean distance from the Sun is about 225 millions of miles, and it travels through its orbit round the Sun in about 1136 of our days: whether it revolves on its axis is not yet known, on account of its small dimensions. This planet was discovered last of the four, but is nearer to Mars than the others.

Ceres is about 285 millions of miles from the Sun, and is about 1760 miles in diameter: it takes about 1680 days to revolve in its orbit round the Sun. M. Piazzi, of Palermo, in Sicily, discovered this planet on the first day of this century; it appears like a star of the eighth magnitude, and has a ruddy colour.

Pallas is about as far as Ceres from the Sun, and goes round him in about four years and eight months. This planet is stated to be rather smaller than the Moon in size. It was discovered by Dr. Olbers in 1802.

Juno's distance from the Sun is about 301 millions of miles, and it revolves round the Sun in about four years and four months: the diameter has been stated at about 1500 miles. Its apparent size is similar to that of Ceres. It was discovered by M. Harding of Lilienthal, in 1804.

In speaking of these little planets, it is necessary for us to remark that any statements as to their diameters are not much to be depended upon: the extremely small diameters which they present to the eye deprive

the astronomer of much of the groundwork on which he builds his calculations. In fact, not only are these planets not seen with the naked eye, but they cannot be observed at all, except with the very best instruments. It is well known that the appearance of the largest and brightest of them, as seen through the instruments at the Greenwich Observatory, is only similar to that of stars of the sixth magnitude; and, when any one of these planets is among stars of such magnitude, it is impossible to distinguish the planet from the stars; and it has often occurred that one of the fixed stars has been taken for the planet, and observed for a good while in its stead.

In respect of the position of these little planets in the solar system, we may remark that there was formerly considered to be, as noticed further on, a wider interval than the proportions of the solar system allow, between the orbits of Mars and Jupiter; so wide, indeed, that many astronomers had predicted that some new planet would, at one time or other, be discovered between them. Now it so happens that the four asteroids are very close together, and just at the distance from the Sun at which a new planet might be expected to lie: it is supposed, therefore, by some philosophers, that these four small planets are fragments of a larger planet which once moved in an orbit nearly coincident with the general position of these little planets. What mighty convulsion of Nature could have produced such a catastrophe, we can only conjecture: nothing for certain on such a subject can be known to us, except that "He who could make could also destroy."

It should be observed that the Sun's apparent motion

is always in the ecliptic; or rather, this is the path of the Earth among the fixed stars, as it is seen from the Sun. The Moon and all the other planets move within the Zodiac, which is 16° broad; the ecliptic being a line dividing it into two equal parts. The distance of the Moon or of any planet from this line, northward or southward, is the *latitude* of such heavenly body. The latitude of the Moon and the six planets is never greater than 8°, so that they are always *within* the Zodiac; but the asteroids, having oftentimes a greater latitude than 8°, are termed *ultra*-zodiacal, their orbits not being confined within the Zodiac.

Many astronomers are, however, of opinion that the largest of these planets, Ceres and Juno, have not a diameter of more than one hundred miles, and that their average density is about twice that of water. Pallas is said to have a very hazy and extensive atmosphere.

In respect of the orbits of Ceres and Pallas, it should be observed that, though the annual period of the latter is longer than of the former, and though, in mean distance, it is a superior and more remote planet, yet, owing to the greater eccentricity of its orbit, its circumference is smaller than that of Ceres. These orbits, therefore, intersect each other, and may eventually lead to a mutual disturbance between the two bodies in question, unless some extraneous circumstances, such as the attraction of the larger planets, operate to prevent it.

JUPITER.

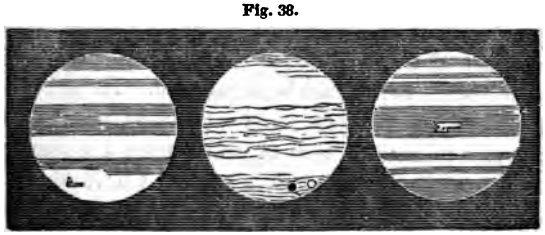
Beyond the sphere of Mars, in distant skies,
Revolves the mighty magnitude of Jove,
With kingly state, the rival of the Sun.
About him round four planetary moons,
On earth with wonder all night long beheld
Moon above moon, his fair attendants, dance.

This is the greatest of all the planets, and consequently the brightest; except Venus, when she approaches near to the earth. Jupiter is an oblate spheroid, his greater diameter being more than 89,000 miles. Owing to his revolving so rapidly on his axis, —the diurnal rotation being completed in ten hours,— he is more flattened than any other planet; his greater diameter exceeding the smaller by 6000 miles,—more than three-quarters of the whole diameter of the Earth. He moves round the Sun in about 4332 days, which is nearly twelve years, by which his motion in his orbit is about 25,000 miles in an hour; while the motion of any spot on the protuberant part of his surface, due to the rotation on his axis, is about 26,000 miles an hour, which motion is more than twenty-five times as rapid as the rotatory motion of the Earth. His mean distance from the Sun is computed at 490,000,000 of miles; whereby, if light and heat diminish as the distance increases, the inhabitants of this planet receive only one twenty-fifth of the light and heat which we enjoy. This deficiency, however, is made up in great measure by his turning round so quickly again to the Sun, in his rotation on his axis, and likewise by the presence of four attendant moons. It is about 1300 times larger than the Earth.

The axis of Jupiter being perpendicular to the plane of his orbit, the seasons in this planet must remain constant, and the days and nights always of the same length.

This planet, like most of the others, appears larger in opposition than in conjunction; it being nearer the Earth in the former case than in the latter. In opposition he subtends an angle of 46″, and in conjunction an angle of 30″. His form, as seen through a good telescope, is oval; the equatorial diameter being to the polar as 13 to 12. The density of this planet is one twenty-fourth greater than that of water; but, nevertheless, owing to his vast bulk, it has a disturbing influence on the bodies of other planets, comets, &c., and the force of gravity at his surface is eight times that of the Earth. His orbit makes with the ecliptic an angle of about $1\frac{1}{4}°$.

Fig. 38.



TELESCOPIC APPEARANCES OF JUPITER.

When this planet is viewed through a telescope, he appears to be surrounded by several belts, as may be seen in the preceding figure, which are all parallel to one another: sometimes these belts are reduced to one or two in number, while at other times they amount to seven or eight; from which it has been conjectured

that these belts are not existent on the body of the planet, but are caused by certain fluctuations in his atmosphere: sometimes they continue without manifesting any change for two or three months, while at other times they alter their appearance in the course of an hour. Of these *zones*, or belts, the darker parts are also supposed to be the body of the planet appearing through a luminous, but cloudy atmosphere.

One of the most remarkable circumstances connected with the planet Jupiter is, the existence of four little moons, which revolve round him in the same way that our Moon revolves round the Earth. The world owes the discovery of these satellites to Galileo:—they were the first fruits of the invention of the telescope, for which we are also indebted to him. Having perceived that a convex and a concave lens, placed in certain positions with respect to each other, gave an enlarged view of an object seen through them, he conceived the grand idea of applying such a combination to the exploration of the heavens, by which the limited power of the human eye could be augmented. He did so: he placed two such lenses in an organ-pipe, which served him as a tube; and thus he constructed the first telescope which the world ever saw*. On turning this telescope towards the planet Jupiter, he perceived a small star near him; and at different times afterwards he discovered three others, all near the planet: these little stars were found to revolve round the planet; for they would come in front of his illuminated surface, travel to one side, pass round behind him, and emerge on the other side, just as Venus and Mercury do round

* See TOMLINSON'S *Manual of Natural Philosophy*, p. 500.

the Sun. He took them at first for *telescopic* stars, that is, stars seen only by means of the telescope. It was about the year 1610, when this discovery took place.

These satellites may be seen with a telescope which magnifies thirty times, or with a considerably lower power, if the atmosphere be very pure. They revolve round Jupiter in various times;—the first being one day, eighteen hours; the second three days, thirteen hours: the third seven days, three hours; and the fourth sixteen days, sixteen hours:—these numbers are approximations sufficient for our present purpose. Their distances from Jupiter are about as follow:—first, 260,000 miles; second 420,000 miles; third, 650,000 miles; fourth, 1,150,000 miles. These planets are about the size of the Earth, some being a little larger and the others a little smaller than the Earth; the first is about one-third, the second three-fourths, the third one-half, and the fourth one-third of the Earth's diameter.

The passage of these little satellites in front of the illuminated surface of Jupiter and behind him, has been of great service to astronomers: first, in determining that light does not pass instantaneously from one place to another, however rapid its motion may be; and secondly, in laying down the longitude of places on the Earth's surface. The satellites can seldom be seen on the body of the planet, even with the aid of a telescope, except just at the time of apparent contact; when the satellite, by being somewhat nearer to the Sun,—the source of light to the whole system,—appears a little brighter than the planet behind it. They are, *however, sometimes* seen as darkish spots on the illumi-

nated disk of Jupiter: this has been attributed to the existence of spots on the surfaces of the satellites, similar to those which we observe on the surface of our Moon. This opinion is further supported by the fact that the same satellite will appear as a bright spot at one time, and as a dark one at another; probably on account of its exhibiting a different side to the Earth at one time from that which it presents at another.

It is remarkable that all these little satellites resemble our Moon, in the circumstance that they revolve on their axes, respectively, in the same time that they revolve round the primary planet Jupiter: this fact has been determined by the same means which enable astronomers to establish the like fact with respect to our Moon, namely, the constant position of certain spots on their surfaces with regard to the situation of Jupiter, although these greatly vary as seen from the Earth; a consequence of this fact is, that these moons always present the same sides towards Jupiter.

As the orbits of three of these are nearly coincident with the orbit of Jupiter, it follows that the Sun suffers an eclipse, as seen from Jupiter, whenever either of these moons is new, or between Jupiter and the Sun: this phenomenon can, by the aid of good telescopes, be seen from the Earth, notwithstanding the immense distance which separates the Earth from Jupiter: a faint shadow is seen to traverse the surface of Jupiter, occasioned by the passage of one of his satellites between him and the Sun. The eclipses, which are, however, most distinctly visible from the Earth, are those in which the satellites themselves are eclipsed, by passing into the shadow of Jupiter, behind the body of the planet: the very short period which they occupy in

going round their primary planet, Jupiter, renders these eclipses extremely frequent.

To an observer on the Earth, there is perhaps no spectacle in the heavens more interesting. With a tolerably good telescope they may be seen distinctly, at one time all in the same straight line on one side of the planet; at another, part on one side and part on the other, but still in a straight line. If they be watched for a few hours they will be seen to change their relative positions; and after a while some or other of them will pass into the shadow behind Jupiter, and so they will become invisible; this is called an *immersion*. The act of coming out of the shadow is called an *emersion*. These are in fact eclipses, or occultations; and they occur with great frequency on account of the quick revolutions of these moons round the planet. The same may be said of the transits of the moons over the disk of the planet.

The times of the immersions of Jupiter's satellites in the shadow of the planet, and of their emersion, as likewise of the transits of these bodies over the face of the planet, are given in calendars, devoted to astronomy, in order to furnish a means for knowing the longitude, or the difference of meridians, on the Earth's surface. The times given in the Nautical Almanack, White's Ephemeris, &c., are adapted to the meridian of Greenwich: so that, if at any other meridian, an observer notice an immersion or an emersion of one of these satellites, or the beginning or end of its transit over Jupiter's disk, to take place one hour, for instance, sooner than the time specified for Greenwich, he knows that he is 15° west of Greenwich; because the Sun in passing round the Earth, must make noon and other con-

sequent periods of time sooner to the eastern parts of the world, than to the western; and as he passes over 15° of the Earth's surface in one hour, by reason that the Earth revolves once on its axis in twenty-four hours, it follows, that to a person situated 15° westward, it will be, for instance, only 11 o'clock, when it is noon at Greenwich. If the observer notice the fact as occurring one hour after the Greenwich time, he may be sure that he is 15° east of Greenwich.

Before Jupiter is in opposition, or so long as he passes the meridian in the morning, the shadow lies west of the planet; and the immersions happen on that side: but after the opposition, the immersions happen to the east.

This method of finding the longitude is more or less accurate according to the practice of the observers, the goodness of the instrument, and the correctness of the tables. The immersion and emersion of the first satellite,—that whose orbit is nearest to the body of the planet,—serves the purpose of the longitude most effectually; the motions of this body being more clear and defined than of the others.

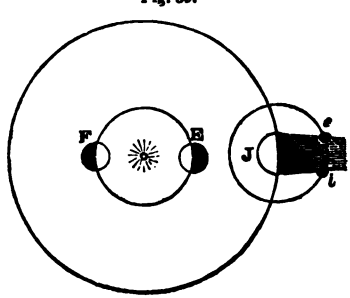
Observations respecting the *progressive* motion of light were first made by noticing these little attendants of Jupiter. It had been usual to consider that light was sudden and instantaneous in its effects. "But there is something so strange in the circumstance that light, as far as the evidence of the senses is concerned, should appear to occupy absolutely no time at all in travelling from place to place, that philosophers have applied many tests, by which they hoped to ascertain whether any portion of time could be estimated during its transit from one station to another. All means,

however, failed till about the year 1675, when Römer, an eminent Danish philosopher, ascertained that light occupies an appreciable, but still very small, portion of time in travelling from the Sun to the Earth. The circumstance which enabled him to determine this important fact was, that the eclipses or immersions of the four little moons, which revolve round the planet Jupiter, did not occur precisely at the periods which calculation had assigned for them; the variation being greater at one period of the year than at another period, six months before or after. From this circumstance he concluded that when the apparent error was greatest, the light traversed a longer path in coming from those little moons to the Earth; and that so the last gleam of light shed previously to a moon's disappearance behind the body of the planet, did not reach the eye until some time after the commencement of the immersion; hence, the retardation would of course be increased, as the distance of Jupiter from the Earth increased. Reasoning from these data, Römer came to the conclusion that the transference of light is *not* instantaneous; but that, like every known agent, it occupies a portion of time in traversing a certain space. Knowing the distances of the principal heavenly bodies from each other, and testing those distances by the apparent retardation of the eclipses of Jupiter's satellites, Römer computed that light traversed the distance from one point of the Earth's orbit to the opposite point, in about eleven minutes: subsequent calculations, however, have proved this to take place in about sixteen and a half minutes; so that eight and a quarter minutes is the time employed by a ray of light in travelling from the Sun to the Earth; which, being a distance of about

ninety-five millions of miles, gives, in round numbers, a velocity of nearly 200,000 miles in a second."—TOMLINSON'S *Manual of Natural Philosophy*, p. 395.

This subject may be well illustrated by reference to the following figure. If we suppose that Jupiter is, upon an average, about 500 millions of miles from the Sun, and the Earth about 100 millions of miles, then, if Jupiter be in conjunction, or the Sun be between Jupiter and the Earth, the Sun's rays must travel about 500 millions of miles to Jupiter or his Satellites, and then, after reflexion, about 600 millions of miles back to the Earth, or 1100 millions of miles altogether; whereas, if Jupiter be in opposition, or the Earth be between the Sun and this planet, the two journeys of the solar rays amount only to 900 millions of miles, which gives the difference, in point of time, first noticed by Römer.

Fig. 39.



In the preceding figure, let J be Jupiter, *e* a satellite entering its shadow, and *i* a satellite emerging from it. *When the* Earth is at E, Jupiter is in opposition, but *when the* Earth is at F, the planet is in conjunction

h' the former case, the solar rays reflected from the tellites have not so far to travel as in the latter.

SATURN.

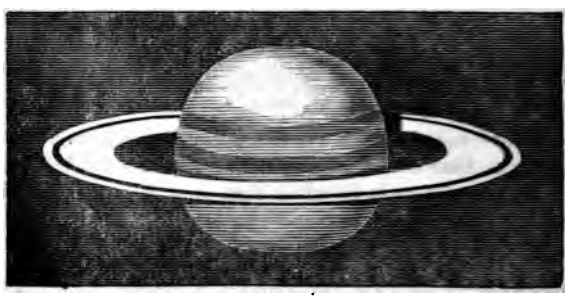
Last, outmost Saturn walks his frontier round,
The boundary of worlds, with his pale moons,
Faint glimm'ring through the gloom which night has thrown
Deep-dyed and dead, o'er this chill globe forlorn:
An endless desert, where extreme of cold
Eternal sits, as in his native seat,
In wintry hills of never-thawing ice.
Such *Saturn's* earth; and even here the sight,
Amid these doleful scenes, new matter finds
Of wonder and delight! a mighty *ring!*

This planet is distinguished from every other body i the heavens, so far as discoveries have yet gone, in ie circumstance of being surrounded by a flat lumi- ous ring, extending to a considerable distance from the dy of the planet, in a manner analogous to the ooden horizon of an artificial globe. Till within sixty ears ago, it was considered to be the furthest of all the lanets; as we find the poet speak of it above.

Saturn revolves round the Sun in an orbit, the mean istance of which from the Sun is about 900 millions of iles, about $9\frac{1}{2}$ times that of the Earth from the Sun: is diameter is about ten times, and his whole mag- tude about 1000 times, that of the Earth; and the in appears to him to have not above $\frac{1}{80}$th part of the sk, or area, which he presents to the Earth; conse- iently, the light and heat received by Saturn from e Sun are less than that received by the Earth in the me ratio. Some persons have computed it to be

about 500 times as much as that which is afforded by our full moon; whereas our sunlight is estimated at 300,000 times that of our moonlight.

Fig. 40.



TELESCOPIC APPEARANCE OF SATURN.

Saturn travels in his orbit about 21,000 miles an hour, and takes up nearly thirty years in passing once round the Sun. He revolves once on his axis in about 10¼ hours. The revolution on his axis produces the same effect as on other planets, namely, flattening him at the poles, and occasioning a protuberance at the equator: the two diameters have been stated as being about in the ratio of 2281 to 2061; it is, however, remarkable that the greatest diameter is not at the equator, but at a point nearly mid-way between the equator and the poles,—this gives to Saturn somewhat the appearance of a square with rounded corners, as may be observed in the figure above. This was one of the earliest subjects for discovery with the telescope. The density of this planet is about one half that of water. His orbit makes an angle of nearly 2½° with the ecliptic; that is, this planet may have that latitude: and his axis is inclined to his orbit at an angle of about

60°; which makes a great variety of seasons, though these be slow in coming round. His apparent diameter is, owing to his great distance, much the same at every part of his orbit, and subtends an angle of about 18″. He may be seen in the heavens without the aid of a telescope, if we know at what place to look for him. His disk is crossed by obscure zones, or belts, like those of Jupiter, which vary in their figure according to the direction of the rings.

When Galileo first presented his telescope towards Saturn, he perceived what appeared like two small bodies at the sides of the planet; and he thought at first that this planet was made up of three stars. It was soon found, however, that these lateral appendages changed their appearance, and assumed the form of a *ring* surrounding the planet. If we encircle a ball with a flat ring, and hold it in a particular position, the ring will appear as nothing more than a *line* across the ball; but, if we incline the latter a little, the ring will appear somewhat oval, or elliptical; and if we turn it round a quarter of a circle from its first position, the ring will appear as a *perfect circle.* Now the same thing occurs with regard to Saturn, except that we never see the ring as a *perfect* circle: it is sometimes a line, when the eye is in the plane of the ring; and at other times an ellipse, when the eye is inclined to that plane. The ring does not touch the planet; for a dark vacant space can be seen between them: indeed, the whole would appear dark, were it not that the Sun's light is reflected from it to the Earth: it does not shine by light reflected from the planet, but by that which is derived from the Sun; therefore there are some positions of the Sun, Earth, and Saturn, when the ring is

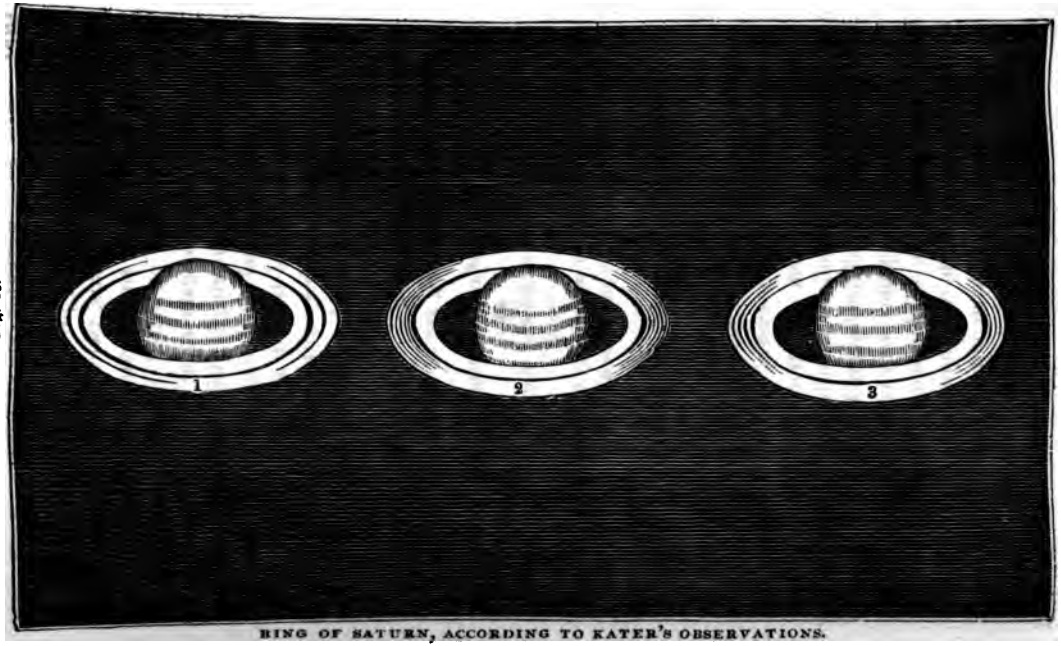
invisible to us. The ring presents its edge towards the Earth every fifteen years, twice in the planet's revolution, but is seen as an elongated oval between those periods: in 1833 it presented its edge towards the Earth, and will do so again about 1848: at present the northern surface of the ring is visible to the Earth.

Sir William Herschel made many careful observations on this ring, and found that it actually consists of two rings, one within another, with a dark space between them; the ring was found to reflect a stronger light than the body of the planet, and to cast a shadow on the planet, thereby proving its opacity. The latest measurements of this ring are as follow:—

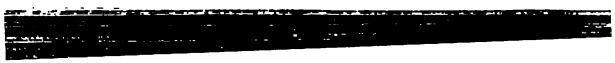
	Miles.
Exterior diameter of exterior ring	176,418
Interior ditto ditto	155,272
Exterior diameter of interior ring	151,690
Interior ditto ditto	117,339
Equatorial diameter of the body of the planet	79,160
Interval between the planet and interior ring	19,090
Interval of the rings	1,791
Thickness of the rings not exceeding . . .	100

Some observers have noticed, that not only does the entire ring appear divided into *two*, but the outer one is likewise subdivided into *several* concentric rings; this, however, has not been confirmed by Herschel and Struve, who have examined it with the finest telescopes ever constructed. The late Captain Kater, about the year 1825, examined this planet very carefully, and noticed the apparent division of the *outer* ring into several circles, as represented in the engraving. It seems that this circumstance had been noticed many years before by Mr. Short; and it had been considered as first settled by the elder Herschel, that there were altoge-

Fig. 41.



RING OF SATURN, ACCORDING TO KATER'S OBSERVATIONS.



ther *two* rings; but, according to Kater's report, he saw in 1825 not only the two rings, but the outer ring appeared to be divided into two parts by a strong black line, as at fig. 1, and each part to be subdivided into at least two others by fainter black lines, as at fig. 3. A drawing made by another person of this appearance is given at fig. 2. Great doubt has been expressed relative to the fact of the outer ring being thus subdivided. Continued observation was interrupted at the time by the ring disappearing, in consequence of the Earth coming into its plane: but the subject will probably not be lost sight of by those who have the best means for observation; and, as the ring is now again expanding to view, the opportunity is afforded for deciding whether the effects noticed by Kater arose from an optical delusion, or corresponded with the phenomena of the belts and zones, which cross the bodies of Jupiter and Saturn. Some astronomers have imagined these rings to be a vast assemblage of satellites. They certainly serve the purpose of many thousand satellites, and, together with the seven acknowledged moons, probably make up the deficiency in the solar rays coming from such an extreme distance.

Seven satellites, or moons, have been discovered to pass in orbits round the planet Saturn. Two of these moons, the nearest to the body of the planet, were discovered by Herschel with his great telescope. The most distant of the satellites is much the largest, and the next is a very conspicuous object with a good telescope; the next three are very minute, and cannot be seen without very good telescopes, while the two innermost have never been seen, except with the most powerful and finished instruments made by man. The

ring and satellites of Saturn serve, in fact, to test the light and distinctness of telescopes.

But, however useful these moons and rings may be to the inhabitants of Saturn, they do not, as the moons of Jupiter, answer any directly useful purpose to the inhabitants of the Earth. Their great distance, and the consequent difficulty of seeing them, render them nearly useless, with reference to the longitude. We leave them, therefore, to act their part as Providence has appointed them, though we cannot but gaze upon and think of them with astonishment, and admiration of the all-surrounding power of the Almighty.

> One *Moon* on us reflects its cheerful light;
> There, seven attendants brighten up the night;
> Here, the blue firmament bedecked with stars;
> There, over head a lucid *arch* appears.

The ring revolves round the planet in about 10 hours and 32 minutes, and in the same plane; which rapidity of revolution gives it a centrifugal force, which keeps it at its due distance in equilibrium.

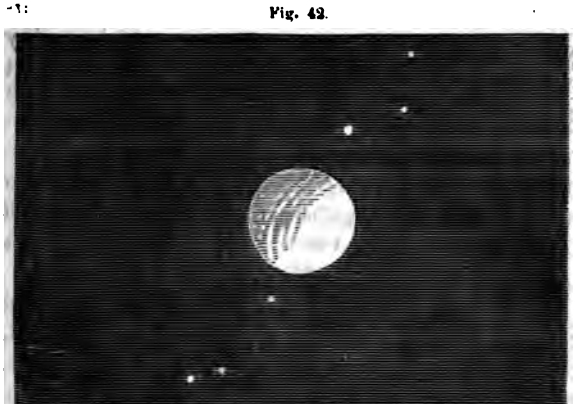
URANUS.

> From *Earth*, how large, how strong, the Sun's bright ball!
> But seen from *thence*, how languid and how small!
> When the keen north, with all its fury blows,
> Congeals the floods, and forms the fleecy snows,
> 'Tis heat intense to what can there be known;
> Warmer *our* poles than is *its* burning zone:
> Who there inhabit, must have other powers,
> Juices, and veins, and sense, and life, than ours.

This is the last and remotest planet in the solar system, as at present known. It is distant from the Sun the enormous quantity of 1800 millions of miles,

being about 19 times further from the Sun than the Earth is; he is about 35,112 miles in diameter, and revolves round the Sun in about 83 years and 150 days: this is the year of Uranus. His summer half-year, therefore, is upwards of 41 of our years, and his winter half-year equally long. The surface of the Sun appears from this planet not above $\frac{1}{368}$th of that which it appears to the Earth; the light and heat received by Uranus are, therefore, smaller in the same proportion. Hence it is quite impossible that any such a fluid as water could exist in that planet, for all would be frozen; and no inhabitants, constituted as the inhabitants of the Earth are, could exist on its surface. Its light from the Sun has been estimated at about the quantity which would be afforded by 240 of our full moons.

Fig. 42.



THE PLANET URANUS.

This planet was discovered by Sir W. Herschel, at Bath, on the 13th of March, 1781, by means of an

excellent telescope constructed by himself, which magnified several hundred times. The first circumstance which led him to think that it was a *planet*, and not a fixed star, was that, although it appeared like a star of the seventh magnitude to the naked eye, yet it appeared as one of the first magnitude when seen through his telescope. Now one consequence of the immeasurable distances of the fixed stars is, that they do not appear larger when viewed through a telescope than when seen with the eye, the only difference being an increase of brilliancy. From the circumstance, therefore, of its increased magnitude, Herschel concluded that this celestial body was not a fixed star, but a comet; subsequently, however, he arrived at the conclusion, that it was a planet moving round the Sun: to this conclusion he was led by observing its continued proximity to the ecliptic, and its motion among the fixed stars from west to east.

This planet subtends an angle of about 4″, which never appears to vary, owing to the comparative smallness of our orbit. Its disk appears uniformly illuminated, and without rings, belts, or spots. Its bulk is however 80 times that of the Earth, and is supposed to be not quite so dense as water. The orbit of this planet is inclined at an angle of 46′ to the ecliptic.

It is just possible to see this planet with the naked eye on a fine clear evening, when the Moon is absent, but it has rarely been noticed without the telescope, when it appears of a blueish white colour. It is said to have been seen before, but to have been regarded as a *fixed star*. Tycho Brahé, we are told, set it down in his catalogue of the fixed stars; as also did Professor Meyer, of Gottingen, in the year 1756.

When discovered to be a planet, Herschel dignified it with the name of the *Georgian Sidus*, or *Georgian star*, in honour of his royal patron, George the Third, and by this name it was known in the *Nautical Almanack*. Foreign astronomers call it *Herschel*, from the name of its discoverer; but the Royal Academy of Prussia, and some others, called it *Uranus*, by which name it is now usually known.

At different times Herschel discovered six satellites moving round this planet, for the same purpose probably as those of Jupiter and Saturn move round those bodies; but these satellites are distinguishable only by the highest telescopic means afforded by art. Two were easily marked out by Sir W. Herschel; but the others, together with the two innermost moons of Saturn, are the most difficult objects in the solar system to get a sight of. It is considered to be a very remarkable fact, that the planes of the orbits of the satellites of Uranus are nearly perpendicular to the ecliptic, and that the motions of these satellites in these orbits are *retrograde*, or from east to west, which is contrary to the order of the signs: but, owing to the very great difficulty of observing these attendant bodies, we have not any decided knowledge respecting their masses and motions.

The discovery of this planet and his satellites was one of the triumphs of the Reflecting Telescope, thus beautifully alluded to by the poet:—

> Delighted Herschel, with reflected light,
> Pursues his radiant journey through the night;
> Detects new guards, that roll their orbs afar,
> In lucid ringlets round the Georgian star.—DARWIN.

CHAPTER X.

LAW OF ATTRACTION OF PLANETS. POWERS OF NUMBERS. PROPORTIONAL SIZES AND DISTANCES OF THE PLANETS. CELESTIAL GLOBE—ITS MOTION AND USES. AMPLITUDE AND AZIMUTH. FIXED STARS CANNOT BE MAGNIFIED. APPARENT DECREASE OF SIZE BY DISTANCE. ZODIACAL LIGHT. CONTEMPLATION OF THE SOLAR SYSTEM.

THERE are some important circumstances connected with the planets, as a system, to which we must now allude. In our second chapter, when speaking of the attraction of gravitation, we stated that each body attracts others in proportion to its mass or quantity of matter. Now, one consequence of this is, that a given bulk of any substance would weigh differently at the surfaces of the different planets. That planet which is larger will attract a body which is upon its surface, towards the centre, with more force than a planet which is smaller; and it is this attraction from the surface towards the centre which constitutes the whole of what we mean by *weight:* consequently, a given mass of matter will weigh more on a large planet than on a small one, supposing the density to remain the same; but as we have already seen that the densities of the planets vary, the forces of their relative attractions must be estimated by the increased or diminished density of the mass, as well as by the actual extent or diminution of size.

There has been noticed a remarkable ratio between the distances of the planets from the Sun. As we shall have to speak of the *power* of a number, we may

as well here state that it means a *number multiplied by itself* one or more times. Thus 2^3 means that 2 is to be multiplied into itself twice, or that three twos are to be multiplied together. If, now, we call the mean distance of the Earth from the Sun 10, then the mean distances of the other planets are nearly as here follow:—

Mercury's distance	. . . . .	=	4
Venus's	„ . = 4 + 3 . . .	=	7
Earth's	„ . = 4 + 3 × 2 . .	=	10
Mars's	„ . = 4 + 3 × 2^2 . .	=	16
Asteroids'	„ . = 4 + 3 × 2^3 . .	=	28
Jupiter's	„ . = 4 + 3 × 2^4 . .	=	52
Saturn's	„ . = 4 + 3 × 2^5 . .	=	100
Herschel's	„ . = 4 + 3 × 2^6 . .	=	196

Now, we must observe that this tabular law was formed by Professor Bode of Berlin, in the year 1772, before the discovery of the Asteroids and Uranus; and that the void occurring between Mars and Jupiter led several German astronomers to suspect the existence of a planet in that point of space; which surmises received a confirmation by the discovery of the four ultra-zodiacal planets at the beginning of this century; while the law itself had been already confirmed by the discovery of Uranus, as a planet, many years before.

As a curious but faithful illustration of the proportional sizes and distances of the planets, referred to the Sun, we quote the following from Sir John Herschel.

"Choose any well levelled field or bowling-green. On it place a globe, two feet in diameter: this will represent the Sun; Mercury will be represented by a grain of mustard-seed, on the circumference of a circle 164 feet in diameter for its orbit; Venus, a pea, on a

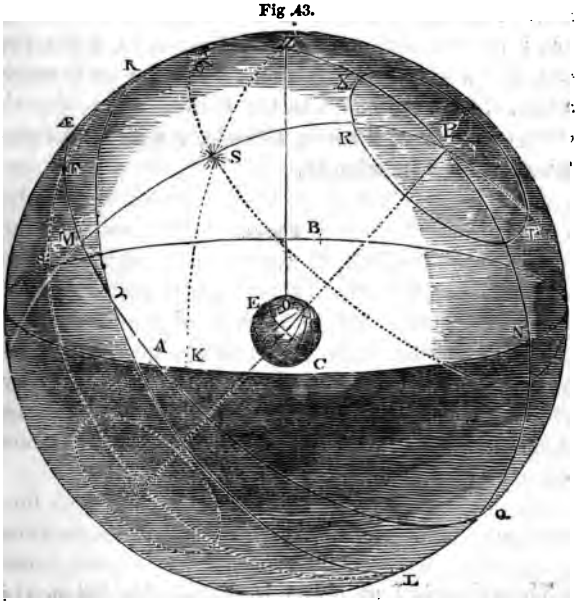
circle 284 feet in diameter; the Earth, also a pea, on a circle of 430 feet; Mars, a rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1000 to 1200 feet; Jupiter, a moderate-sized orange, in a circle nearly half a mile across; Saturn, a small orange, on a circle of four-fifths of a mile; and Uranus, a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter."

But when the student of Astronomy shall have come to form a just estimate of the extent of the solar system, and the magnitudes of its component masses, he will yet refer all the members of it, together with the other celestial bodies, to the great concave sphere of the heavens, on which he will trace their various paths, real and apparent. Hence we arrive at the motion and uses of the celestial globe; on which the fixed stars are laid down in their several constellations, and by which the course of the Sun, and the paths of the Moon and planets among the stars, may be readily and conveniently traced.

For this purpose, the following figure, (fig. 43,) furnishes the rudiments of the celestial globe; for, as when a person uses this globe, he must fancy himself placed at its centre, so, when we direct our attention to the great circles of the heavens, by means of which we estimate the positions and motions of the heavenly bodies, we consider the Earth as the central point, as shown in the figure. The axis of the Earth being produced both ways, meets the surface of the great sphere of the heavens, at P and V. These are the poles of the heavens, about which the stars have their apparent or diurnal paths, at right angles to the terrestrial axis, as

is seen in the motion of the star at S. If the Earth's equator, E C, be carried out to the heavens, the great circle thus formed, Æ Q, is the equinoctial. The *declination* circles are those which have their centre at the

Fig 43.

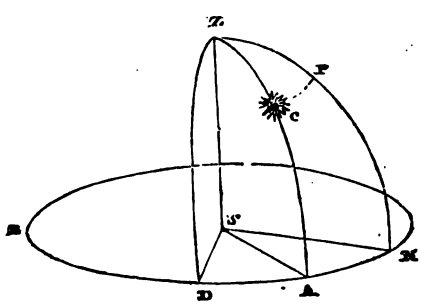


centre of the Earth, and which are at right angles to the equinoctial; such as P S M. The use of these circles is to determine the situation of a star, &c.; as the latitude of a place on the Earth's surface is reckoned on a meridian. This is the computation for north or south; and as on the terrestrial globe it is necessary to know the east or west distance from a meridian, so, on the celestial globe, this is noted from the first point of

Aries, thus marked, ♈. This computation goes on eastward round the globe, and is called the star's *right ascension*.

Again, let O be a spot on the Earth's surface, then Z is its zenith; the nadir being opposite, on the other side. Again, let N B S A be the horizon of O; then N and S are the north and south points, and A and B the east and west points. A circle, Z S K, drawn through a star, S, from the zenith to the horizon is the azimuth circle of the star, K S is its altitude, Z S its zenith distance, and K N its azimuth.

Fig. 44.



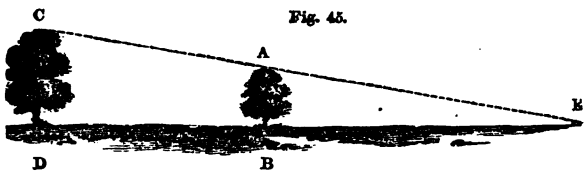
The *azimuth* of an object is the angular distance of the horizontal point directly under that object, from the north or south points of the horizon. Thus, in the preceding figure, if S be the observer, Z his zenith, Z N his meridian, N A B the horizon,—then Z A will be the vertical or azimuth circle passing through a heavenly body, C, and cutting the meridian at the zenith, Z, and also at the nadir, which is exactly opposite to Z on the celestial sphere:—Z D will be the prime vertical or azi-

muth circle passing through the east and west points of the horizon: the arc of the horizon, N A, or C P above, measured in degrees, is the azimuth of the heavenly body, C, and the arc, A D, is the amplitude of the same. A consideration of these few particulars will prepare the reader for the study of the celestial globe.

It is exceedingly curious, as matter of observation to the young astronomer, that the different planets, the members of the solar system, admit of being magnified, or increased in apparent size, according to the power of the instrument with which they are viewed; while the fixed stars, when undergoing the telescopic scrutiny, only cease to twinkle, and remain as bright points, not at all enlarged to the eye. These are, perhaps, the only objects in creation, as far as the range of man goes, which, as to apparent size, are unacted upon to human vision by a combination of lenses. In the cases of other objects, when viewed, the apparent size decreases as the distance increases, and *vice versâ*:— and the use of the telescope is, by bringing the light thrown from the body to a focus, to enable us to see that body under a larger angle. In the following figure, it is clear that the tree, A B, will appear to an observer at E, of the same size as the tree, C D, because both subtend the same angle; whereas, the former tree is much smaller than the latter, but stands much nearer to the observer. Now, if both these trees stood at the same distance from the observer at E, yet, if the tree, A B, were observed through a telescope of a certain power, it might be made to appear of the same size as the tree, C D. Hence we may infer that the Sun and planets, if removed away to the space occupied by the

fixed stars, would appear, if they appeared at all, only as luminous points. In fact, as each fixed star is deemed to be itself the centre of a system of planets, so our Sun is, by parity of reasoning, supposed to be only one of those celestial bodies which we call *fixed stars*.

Fig. 45.



Some of these fixed stars have, as we shall hereafter notice, different colours apparently inherent in themselves. It is curious to consider whether our Sun may not likewise appear as a coloured star, in those regions of the heavens where the fixed stars are situated. Herschel seems to think that the Sun must appear to the other fixed stars as one of the *nebulous*, or cloudy stars; that is, those which are too small, or too remote, to be viewed otherwise than dimly. The cause which leads Herschel to form this opinion is the consideration of the phenomenon, called the *zodiacal light;* thus termed, because it issues from the zodiac, in the middle of which is the Sun's path. This light may be seen any very clear evening, soon after sunset, about the months of April or May, or at the opposite season before sunrise, as a cone of light, extending from the horizon obliquely upwards, and following the course of the Sun's path. It is faint and ill defined in this climate, though better seen in tropical countries; but it cannot be mistaken for any atmospheric meteor, or aurora borealis. It seems to be of the nature of a thin

atmosphere, surrounding the sun, and extending at least beyond the orbit of Mercury, and even of Venus; and it may be conjectured to be no other than the denser part of that medium, which, as we have reason to believe, resists the motions of comets, and which we shall speak of more fully in its proper place. But we cannot be said to know much more about the zodiacal light, than that it is somewhat similar in appearance to the milky way, of which we shall speak hereafter, and that it is connected with the rotation of the Sun on its axis.

Thus have we taken a survey of that part of space which is occupied by the Solar System; the grandeur of which we may make an abstract of, by referring to the language of Chalmers, in his Discourse, entitled *A Sketch of Modern Astronomy.*

"The Psalmist takes a still loftier flight. He leaves the world, and lifts his imagination to that mighty expanse which spreads above it and around it. He wings his way through space, and wanders in thought over its immeasurable regions. Instead of a dark and unpeopled solitude, he sees it crowded with splendour, and filled with the energy of the Divine presence. Creation rises in its immensity before him; and the world, with all which it inherits, shrinks into littleness at a contemplation so vast and so overpowering. He wonders that he is not overlooked amid the grandeur and the variety which are on every side of him; and, passing upward from the majesty of nature to the majesty of nature's Architect, he exclaims, "What is man, that thou art mindful of him, or the son of man, that thou shouldst deign to visit him?"

"It is not for us to say, whether inspiration revealed to the Psalmist the wonders of modern astronomy; but even though the mind be a perfect stranger to the science of these enlightened times, the heavens present a great and an elevating spectacle,—an immense concave, reposing upon the circular boundary of the world, and the innumerable lights which are suspended from on high, moving with solemn regularity along its surface. It seems to have been at night that the piety of the Psalmist was awakened by this contemplation, when the moon and the stars were visible, and not when the sun had risen in his strength, and thrown a splendour around him, which bore down and eclipsed all the lesser glories of the firmament. And there is much in the scenery of a nocturnal sky, to lift the soul to pious contemplation. That moon, and these stars, what are they? They are detached from the world, and they lift us above it. We feel withdrawn from the earth, and rise in lofty abstraction from this little theatre of human passions and human anxieties. The mind abandons itself to reverie, and is transferred, in the ecstacy of its thoughts, to distant and unexplored regions. It sees nature in the simplicity of her great elements, and it sees the God of Nature invested with the high attributes of wisdom and majesty.

"But what can these lights be? The curiosity of the human mind is insatiable, and the mechanism of these wonderful heavens, has, in all ages, been its subject and its employment. It has been reserved for these latter times to resolve this great and interesting question. The sublimest powers of philosophy have been called to the exercise, and astronomy may now be

looked upon, as the most certain, and best established of the sciences.

"We also know, that every visible object appears less in magnitude as it recedes from the eye. The lofty vessel, as it retires from the coast, shrinks into littleness, and at last appears in the form of a small speck on the verge of the horizon. The eagle, with its expanded wings, is a noble object: but when it takes its flight into the upper regions of the air, it becomes less to the eye, and is seen like a dark spot, upon the vault of heaven. The same is true of all magnitude."

"The heavenly bodies appear small to the eye of an inhabitant of this earth only from the immensity of their distance. When we talk of hundreds of millions of miles, it is not to be listened to as incredible. For remember that we are talking of those bodies which are scattered over the immensity of space, and that space knows no termination. The conception is great and difficult, but the truth is unquestionable. By a process of measurement which it is unnecessary at present to explain, we have ascertained first the distance, and then the magnitude, of some of those bodies which roll in the firmament; that the sun which presents itself to the eye under so diminutive a form, is really a globe, exceeding, by many thousands of times, the dimensions of the earth we inhabit; that the moon itself has the magnitude of a world; and that even a few of those stars which appear like so many lucid points to the unassisted eye of the observer expand into large circles upon the application of the telescope; and are some of them much larger than the ball which we tread upon, and to which we proudly apply the denomination of the universe."

"Did the discoveries of science stop here, we have enough to justify the exclamation of the Psalmist, 'What is man, that thou art mindful of him; or the son of man, that thou shouldst deign to visit him?' They widen the empire of creation far beyond the limits which were formerly assigned to it. They give us to see that yon Sun, throned in the centre of his planetary system, gives light and warmth, and the vicissitude of seasons, to an extent of surface several hundred times greater than that of the earth which we inhabit. They lay open to us a number of worlds, rolling in their respective circles around this vast luminary; and prove that the ball which we tread upon, with all its mighty burden of oceans and continents, instead of being distinguished from the others, is among the least of them; and from some of the more distant planets, would not occupy a visible point in the concave of their firmament. They let us know, that though this mightly earth, with all its myriads of people, were to sink into annihilation, there are some worlds, where an event so awful to us, would be unnoticed and unknown, and others where it would be nothing more than the disappearance of a little star which had ceased from its twinkling. We should feel a sentiment of modesty at this just but humiliating representation. We should learn not to look on our earth as the universe of God, but one paltry and insignificant portion of it; that it is only one of the many mansions which the Supreme Being has created for the accommodation of His worshippers, and only one of the many worlds rolling in that flood of light, which the Sun pours around him to the outer limits of the planetary system."

CHAPTER XI.

COMETS—HISTORICAL NOTICES OF—THEORIES AND PHENOMENA OF. ORBITS OF PLANETS AND OF COMETS. COMETS OF HALLEY, ENCKE, AND BIELA. UNDULATORY THEORY OF LIGHT. DIMENSIONS OF THE TAILS OF COMETS.

Comets.

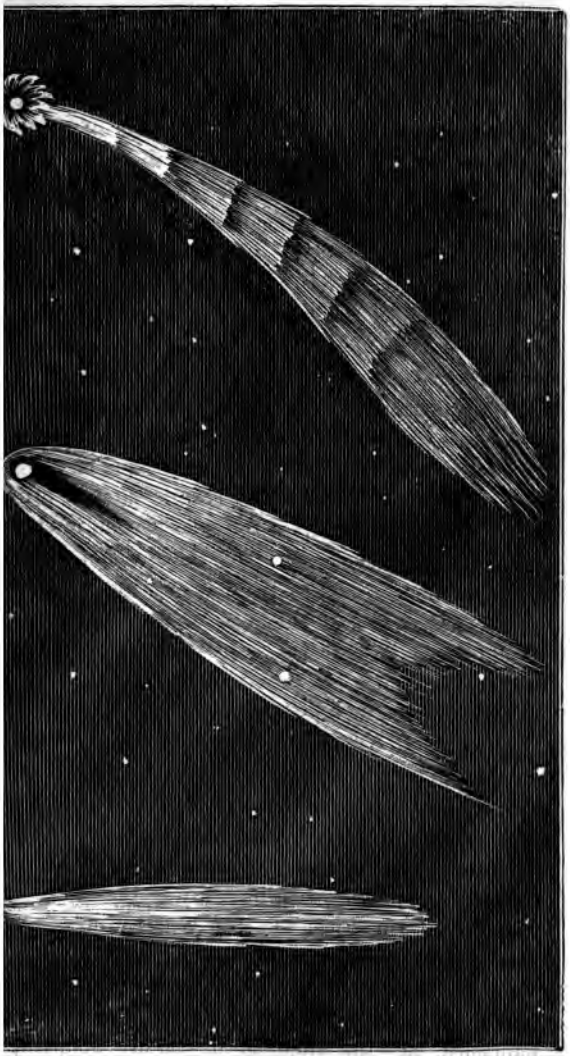
. . . . . Amid the radiant orbs,
That more than deck, that animate the sky,
The life-infusing suns of other worlds;
Lo! from the dread immensity of space
Returning, with accelerated course,
The rushing Comet to the Sun descends;
And as he sinks below the shading earth,
With awful train projected o'er the heavens,
The guilty nations tremble. But, above
Those superstitious horrors that enslave
The fond sequacious herd, to mystic faith
And blind amazement prone, the enlightened few,
Whose godlike minds philosophy exalts,
The glorious stranger hail. They feel a joy
Divinely great; they in their powers exult,
That wondrous force of thought, which mounting spurns
This dusky spot, and measures all the sky;
While, from his far excursion through the wilds
Of barren ether, faithful to his time,
They see the blazing wonder rise anew,
In seeming terror clad, but kindly bent
To work the will of all-sustaining love:
From his huge vapoury train perhaps to shake
Reviving moisture on the numerous orbs,
Through which his long ellipsis winds; perhaps
To lend new fuel to declining suns,
To light up worlds, and feed th' eternal fire.—Thomson.

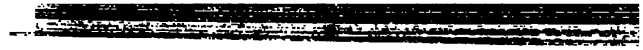
THERE are but few objects in creation, which ex[cite] more wonder and interest than those comets which [appear] accompanied by long trains, or tails, of lumin[ous] ethereal matter. In the early ages, the most extr[avagant] gant superstition was connected with the appear[ance] of these visitors: whole nations seemed to feel [that] they were under a terrible infliction from heaven; [and] an indescribable awe, which is a general attendan[t] ill-understood or misunderstood phenomena, preva[ils] on the subject. Though this feeling has now in [a] measure passed away, they are still objects of wo[nder] to the uninstructed; and even those who are best [in]formed on the subject, have little better than conjec[tures] to offer respecting them.

The principal reasons why comets do not admit [of] being considered as part of the solar system in the same rank as the planets, is, that they cannot be traced through their orbits with that certainty which the planets can, and that their appearances vary so greatly at different times: it has been even doubted by some whether a comet has any solid body at all, like other members of the solar system.

If we are to believe the narrations of early writers, it would appear that comets were once seen, greatly exceeding in size those which have appeared of late years; from whence it seems that the whole tribe of comets deteriorates, as if, being of an unsubstantial nature, they were gradually wearing away in the course which they describe in space. In the year 130 B. C., a comet was seen so large that it appeared to have the same diameter as the Sun. In the year 60 B. C. a large comet was seen very distinctly near the Sun, which happened at the time to be totally eclipsed, and

Fig. 46.





thereby made the comet visible. The comets which appeared in 1402 and 1532, are reported to have been bright enough to be seen in the sunshine of open day. In 1680 a comet appeared, which possessed many striking phenomena: of this comet, shown in the engraving, we shall speak further on. It had a *nucleus*, which is considered to be the real comet itself, and this was surrounded by an atmosphere, or luminous ring, which assumed the appearance of a *beard*, called the *coma*, (from the Latin for *hair;*) hence the word *comet*, —a *hairy* body. The coma, together with the nucleus, make up the *head;* and, lastly, came a long *train* or *tail*, which extended to a considerable distance across the heavens; according to some accounts as much as 80°: and this is another remarkable characteristic of modern comets, that, together with their star-like appearance, their tails have likewise diminished in extent. A comet seen in the year 371 B. C., had a tail, which extended over 60° of the celestial sphere, That which appeared in the year 1618, is said to have cast a tail of 104° in extent.

At the same time it must be observed that the tail does not necessarily accompany a comet. Many small comets have had immense tails, and many large and bright comets have had no tails. The variety is immense; for the flock of these celestial coursers seems very large, and even countless. Hundreds have been noticed in the records of the world; and, as these are the largest and brightest seen, it is presumed that many, which were small, escaped notice. Very many have been observed of late, and their number is deemed to be illimitable; for all, which are near the Earth, are not always seen, owing to their being on that part of

the heavens which is above the horizon during the day.

The comets of 1585, 1682, and 1763, had no tails. Indeed, the second of these three is described as being large, bright, and flaming, with an appearance like that of the planet Jupiter. But a comet is reported to have been seen in 1744, which had a tail made up of as many as six streams of light, all extending to the distance of 30° over the dome of the heavens.

Very little is known concerning the *nature* of comets: some have asserted that stars have been seen through the nucleus or head of a comet; this, however, is doubtful, as it is more probable that the light from the star is refracted through the surrounding atmosphere of the comet. It seems a more rational conjecture that the body of the comet is opaque; but that, when it approaches so near, as some of them do, to the Sun, all the substances which are vaporizable on its surface are converted into vapour, and form an immense atmosphere round it. This atmosphere, on account of the great velocity with which the comet moves, becomes left somewhat behind, and may, perhaps, furnish an origin for the coma, or the tail. Sir Isaac Newton supposed that the tail of a comet arose from a thin vapour elicited from the comet by the heat of the Sun. Another opinion is, that comets serve the purpose of bringing back to the planets of our system the electrical matter which they constantly throw off: it must be admitted, however, that all is pure conjecture on this point. It has been urged by those who advocate the hypothesis, that the body or nucleus of the comet is opaque, that it exhibits phases similar to those of the Moon, when viewed in different directions; but this

again is denied, for some comets have been watched, when about to cross over the disk of the Sun, and no spot was discoverable upon that luminary. The comet of 1680 approached so near to the Sun, that Newton estimated that it was exposed to a heat two thousand times greater than that of red-hot iron. Newton further conjectured that comets were bodies which gradudually approached nearer to the Sun, and finally fell upon it, and might thus repair the waste supposed to occur from the continual emission of light and heat from the Sun. The discovery of the elliptical orbits of comets, however, deprives this hypothesis of much of its value.

But, in order to come to some definite opinion about the nature or substance of this class of the heavenly host, we have to state that all comets, especially those of modern observation, present a vaporous sort of substance to terrestrial gaze. Their mass becomes denser towards the centre, which appears like a stellar point; and the light, whether encircling this point as a coma, or streaming from it as a tail, seems to have, as it were, the texture of the aurora borealis, and like the latter, to allow of the appearance of the stars through its filmy substance. The more prevalent opinion then, at present, respecting the nature of these beings is, that they are of a flimsy character, and that they are gradually absorbed by the Sun when they come into his neighbourhood: whence it is that every remarkable comet, whose re-appearance has justified the expectations of mankind, has disappointed the crowds who have sought to gaze upon the strange visiter in the skies. Its spare and attenuated aspect has made us wonder what our forefathers of old saw to fear, and to be astonished at;

for if astronomers had not told us when and where to look for them, we should not be aware of their presence.

Comets have great variations in size during the time they are visible. Sometimes they appear as faint objects in the distance, but enlarge by degrees, and throw out a tail, and so increase in brightness and extent till they become lost in the light of the Sun. If, during the time of the comet's *doubling* the Sun, (so to speak,) it lose any of its substance, it seems usually to gain in brightness; the sun-beams seem then most chiefly to promote the splendour of the tail, until the comet, having receded far away from the Sun, disappears like a spirit of ether.

In speaking of the orbits of the various planets, we always refer them to the Earth's orbit as a standard by which their directions in the heavens can be understood; and we say that an orbit is inclined a certain number of degrees to the ecliptic, or Earth's orbit, according as the two orbits deviate much or little from coincidence with each other. Now it so happens that the orbits of all the planets deviate but a very few degrees from each other, while the orbits of the various comets which have been observed, deviate from the direction of the Earth's orbit by angles of almost every amount. A right angle is the largest angle that can exist between two lines, or two planes, and it is found that the orbits of the comets form almost every kind of angle with the ecliptic, from 0 degree (or coincidence) to 90 degrees (or a right angle): this then is one circumstance in which comets differ greatly from the planets. Another point of difference is the *form* of their orbits; the orbits of the planets are in reality elliptical, but the

ellipticity, or the eccentricity,—that is, the amount of difference between the circular and the elliptic form,—is so small, that the planetary orbits differ but very little from circles. Such, however, is not the case with the orbits of the comets; they are, for the most part, exceedingly long, or very eccentric, ellipses; indeed, it was for a long time doubted whether their paths were ellipses at all, or whether they were real orbits. This we must explain. There are two curved lines called parabolas and hyperbolas, to which we may obtain a rude resemblance by considering a bee-hive turned upside down; they terminate at two ends, and do not meet again at any point so as to form an orbit. Now it is susceptible of proof, that, if two of the heavenly bodies were situated in space, and acted on each other by the attraction of gravitation, one of them might have such a velocity and direction of motion given to it, as would make it describe a circle round the other body; or that, by altering the direction and velocity, the body might be made to describe either an ellipse, a parabola, or a hyperbola: in the latter two of which cases, it would never return again to the spot from whence it set out, but would continue travelling on through space for ever, unless acted on by some of the bodies in or near its path.

The question of the orbital motions of comets is referrible to that part of mathematics which is termed the "Conic Sections." The figures obtained by these sections, or divisions, of a cone, are five. If we take a cone, usually compared for shape to a sugar-loaf with a sharp top, and divide it by a line parallel with the base, the figure obtained by this division is a *circle*. If we divide it from the top vertically downwards, the

figure is a *triangle*. These two figures are, however, not taken into account in this department of science, but belong to common geometry. The third section is an *ellipse*, made by cutting the cone from side to side obliquely into two parts. The fourth figure is a *parabola*, made by dividing the cone in a direction parallel with one of its sides: and the fifth figure is the *hyperbola*, made by dividing the cone in a direction parallel with its axis, which is a line descending from the vertex, or top, to the centre of the base.

But there were also circumstances which rendered untenable the opinion, that all comets moved either in parabolic or hyperbolic orbits. Comets appeared after certain intervals, which presented exactly the same features, as to shape, position, and distance from the Sun, as some which had preceded them; and, by certain calculations, it was proved that a comet, moving with the same velocity as an observed comet, would perform a certain revolution in a certain time, and that time was found to correspond with the interval between the appearances of the same comet: this combined process of calculation and observation was applied to several comets; and the result being successful upon certain occasions, it is now considered as proved that some comets move in elliptical orbits about the Sun. When, therefore, we say that the comet which was visible in 1835 was the same which Halley saw a century and a-half ago, we mean that a calculation, founded on the observed motion of that comet, is found to be correctly predictive, on the supposition that the orbit of that comet is elliptical.

What may be the whole number of comets circulating round the Sun, we are totally ignorant: about 150

have been observed with sufficient attention to mark the rates of their motion, their obliquities to the ecliptic, and other particulars, which come under the general name of the *elements* of a comet. Out of this number, however, there are but three whose returns, after certain periods, have been correctly predicted. So vague and unsatisfactory is the knowledge which we possess of these bodies, that only three out of the thousands which probably exist in space, have returned to particular spots in the heavens, at times which had been foretold. These three are named after the astronomers who calculated the periods of their return,—Halley, Encke, and Biela.

In 1531 a comet appeared, of which the velocity of motion, and other particulars, were noted. In 1607 another appeared, which presented similar features to the former. In 1682 Halley, the great astronomer, observed a comet which presented nearly the same features as the two former. Now there is an interval of about seventy-six years between these eras, and Halley thought it probable that there had not been three different comets visible in those three years, but that they were successive appearances of the same comet. On calculating the extent of its orbit, he came to the conclusion that it would complete a revolution about the Sun in about seventy-six years, and he boldly predicted its return in about 1757. It did not appear in that year, but in 1759; and the retardation is considered to have been due to the action of Saturn and Jupiter upon its mass, when near those planets, whereby it was delayed in its journey as much as 618 days. This effect from Saturn and Jupiter was foretold by the French astronomer, Clairaut, who fixed the time of

its coming to the *perihelion*, the *nearest* part of its path to the *Sun*. The event proved his correctness within one month. It again appeared in the autumn of 1835, forming a period of about seventy-six years from the preceding appearance. There is reason to believe that an appearance of this comet can be traced back as far as 130 years B. C.; and that it is the same comet that was seen in the years 323 and 399, when it was described as being of vast magnitude and horrible aspect. This is also supposed to be the comet which appeared in 550, 855, 930, and 1006; in which latter appearance, its nucleus is reported to have been four times as large as the planet Venus. It was seen in 1230, 1305, and 1380, and again in 1456: at this last visit it was accompanied by a tail, which extended over sixty degrees of the heavens, and gave rise to so much terror and consternation, that Pope Calixtus ordered prayers to be offered up from all parts of Christendom, for the removal of the comet and its malign influences. The Turks were engaged at this time in a successful war against Greece; and when Europe was fearing nothing less than subjugation at the hands of the victorious Turks, this comet, having a tail in the form of a Turkish sabre, was regarded by the tribes of the West as the emblem of Divine vengeance. After this, its appearances and progress are regularly recorded to the present times. In the sixteenth century, it is said to have displayed a fine gold colour. Halley, in 1682, describes it as being as large and bright as Jupiter, with a tail of 30°. The inclination of its orbit to the ecliptic is about $17\frac{1}{2}°$. In 1835, the length of its tail to the naked eye was about 6°: with a telescope it appeared larger.

Encke's comet performs its revolution round the Sun in about 1208 days. This comet had been observed in 1789, 1795, 1801, and 1805, and had presented various aspects to an observer; sometimes being accompanied by a tail, and sometimes not. When it appeared in 1818, Encke, professor of astronomy at Berlin, determined the period of its revolution as given above, and predicted its return in 1822. It returned in that year, but was not visible in England; at Paramatta, in New South Wales, however, it was seen: it appeared again in 1825, 1828, 1832, and 1835. It was visible with a good telescope between August and December of last year.

The orbits of these comets are elongated ellipses; which may be strikingly illustrated by the orbits of Encke's and Halley's comet. When the former is nearest to the Sun, it is within the orbit of Mercury; that is, nearer to the Sun than any of the planets; but when it is at its *aphelion*, or greatest distance from the Sun, it nearly approaches the orbit of Jupiter, which is thirteen times as distant as Mercury is from the Sun. Hence, the *aphelion*, or *furthest part* of this comet's orbit from the *Sun*, is ten times more distant from the Sun than the perihelion. Halley's comet, when in perihelion, was between Mercury and Venus; in aphelion, it is twice as far off as Uranus.

The three comets of which we here speak are regular members of the solar system; for they move round the Sun, as their focus, in accordance with the law of gravitation. The inclination of the orbit of Encke's comet to the plane of the ecliptic is about $13\frac{1}{4}°$; and it moves, like the planets, from west to east.

Its present appearance is like that of a small round nebula, without any tail. It is rather brighter at the centre than at the edges; but still its light is so faint, that it is not seen without difficulty. It does not influence any other body of the solar system; but itself suffers some perturbations from the attractions of the planets. Hence we infer that this, like most of the other comets, is little more than a vaporous globe of matter, without any specific solidity.

This comet would be comparatively insignificant, but for the aid which it affords in establishing the undulatory theory of light. According to this theory, space is considered to be filled, apart from the atmospheres of planets, with an extremely rare medium termed *ether*, by the undulations of which light is propagated. This medium, though offering no sensible resistance to the motions of the planets, was thought to be likely, if existing, to impede to a certain extent the passage of so airy a thing as a comet. Accordingly, Professor Encke, having calculated the return of this comet upon the consideration of the *vacuum* of space, the actual time of the comet's return differed two days from the calculated return, in consequence, as asserted, of a resisting operation upon the motion of the comet in its path. But the ultimate effect of this retarding influence was discovered in *hastening*, not in deferring, the time of the appearance of the comet! for, as the all-pervading ether caused the comet to advance somewhat more slowly, the centrifugal force of the comet was diminished, whereby the solar attraction for it was increased; so that, by being drawn gradually nearer to the Sun, the time for its completing its revolution is, in consequence, dimi-

nished. In the course of time, therefore, this comet must fall to the Sun. Like reasonings have been made to apply to other comets, and also to the Earth and the other planets, in order to convey to our minds the great moral lesson, that *all things have an end.* The Psalmist thus addresses the Almighty, (Ps. cxix. 96,) "I have seen an end of all perfection, but thy commandment is exceeding broad;" implying thereby, that all created nature is bounded by limits which, however wide, are within the grasp of the Maker of all things.

Biela's comet had been noticed in 1772 and 1806, and when it appeared in 1825, Biela, a German astronomer of Josephstadt, calculated the period of its revolution, and predicted its return in 1832:—this prediction was fulfilled, and the period of the revolution of this comet is considered to be established at 2440 days. Its last appearance was in 1832. It is spoken of as a small, insignificant comet, without a tail, or any appearance of a nucleus. The inclination of its orbit to the ecliptic is about $13\frac{1}{4}°$; and so near does its path approach that of the Earth at the intersection of the planes, that it is considered that, in 1832, if the Earth had been one month in advance of its annual journey, it would have passed through this comet.

These are the only comets of whose periods we have any certain knowledge. There are, however, two others whose periods have been stated; but the times are not yet arrived for testing the accuracy of the predictions. One of these comets appeared in 1264, and again in 1556—an interval of 292 years; and it is expected again in 1848. The other comet, seen in the

engraving, was observed by Newton in 1680, and he predicted its return in 575 years: a long period must therefore elapse before the truth of this calculation, or conjecture, can be verified. The tail of this comet, which is several times noticed in history, was of such vast extent, that when the head of the comet was in the horizon, the extremity of its tail was in the zenith. This observation was made at Constantinople. Of such sights as these, well might Dr. Young say—

> Hast thou ne'er seen the comet's flaming flight?
> The illustrious stranger passing terror sheds
> On gazing nations, from his fiery train,
> Of length enormous.

A remarkable comet appeared in the year 1770, which was found to revolve in a period of about five years; but the prediction of its return was not verified, in consequence of its getting too near the satellites of Jupiter, which, though undisturbed themselves by the comet, so deranged the motions of the comet as to thrust it from its original path, and it has never been seen again. If this be correct, it shows that the mass of the comet is spare indeed. The comet of Encke is observed to grow less as it approaches the Sun, and to amplify at its departure from the solar presence; owing, it is said, to the vaporizable matter being converted into gas.

The tail of the splendid comet of 1680, noticed by Newton, 120,000,000 miles in length, was observed to issue forth from the head of the comet in two days. This tail, being opposed to the Sun, is supposed to have been caused by the Sun to be emitted. The tail of the comet of 1769 was 48,000,000 miles in length, and that of 1811 was 108,000,000 miles in length.

The diameter of the body of this last was 50,000 miles. It is thought that the matter of the comets is discharged at their tails, by the agency of the Sun; and that the gravitating power of the comet is not sufficient to re-collect it.

CHAPTER XII.

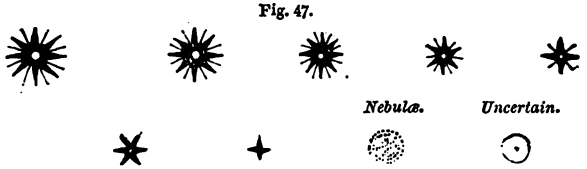
FIXED STARS. GENERAL PARTICULARS. POSITIONS HEAVENLY BODIES. HOW TO DESCRIBE OR F THEM. CLASSIFICATIONS AND DISTINCTIONS OF ST. THEIR PARALLAX. LUNAR DISTANCES, AND THE I GITUDE. THE GALAXY, OR MILKY WAY. DOUBLE TRIPLE STARS, &c. NEBULÆ. STARS CONSIDERED BE SUNS. POLE-STAR. CONSTELLATIONS OF THE GR AND LITTLE BEARS, &c. THE CROSS. SIDEREAL D OCCULTATIONS. SHOOTING STARS.

When I behold this goodly frame, this world,
Of heaven and earth consisting, and compute
Their magnitudes, this earth, a spot, a grain,
An atom, with the firmament compared,
And all her numbered stars, that seem to roll
Spaces incomprehensible (for such
Their distance argues, and their swift return
Diurnal) merely to officiate light
Around this spacious earth, this punctual spot,
One day and night, in all their vast survey
Useless besides; reasoning I oft admire,
How nature, wise and frugal, could commit
Such disproportions, with superfluous hand,
So many nobler bodies to create,
Greater so manifold, to this one use,
For ought appears, and on their orbs impose
Such restless revolution day by day
Repeated, while the sedentary earth,
That better might with far less compass move,
Served by more noble than herself, attains
Her end without least motion, and receives,
As tribute, such a sumless journey brought
Of incorporeal speed, her warmth and light;
Speed, to describe whose swiftness number fails.

THE sublimity and beauty of the starry heavens is such a common subject of remark, that we need not stop to expatiate on it; but we wish to treat of some matters connected with the stars, which have not hitherto engaged our attention.

The stars appear much more numerous at first sight than they are found to be on reckoning those which are visible: this is occasioned by the glittering and twinkling, and the apparent confusion in which they seem mingled together. They have been, as we before stated, clustered into constellations, which are known by certain names; but besides this, they are divided into classes, according to their *magnitudes*, the number of recognised magnitudes visible without a telescope being seven; which is continued, with the aid of powerful instruments, up to the sixteenth. It is, however, necessary to remark, (and nothing can give such

Fig. 47.



MAGNITUDES OF THE STARS, FROM THE FIRST TO THE SEVENTH, AS USUALLY MARKED ON CELESTIAL MAPS.

a striking proof of the immense distance at which they are placed from the Earth,) that, although we speak of *magnitudes*, the stars have really no appreciable magnitude at all: they did not appear larger through Sir W. Herschel's telescope, which magnified 6000 times, than they do to the naked eye; but they appear *much brighter* when viewed through a telescope; sometimes

too bright to be gazed upon without pain to the eye, as we are told is the case when Sirius, the brightest of the fixed stars, appears through a telescope. It is, therefore, more properly speaking, by the *brightness* that we compare different stars, and not by the magnitude. Every star appears through a telescope to be a mere point of light, without appreciable diameter; and this is one of the circumstances which have baffled all the attempts of astronomers to estimate their distances.

The fact of the impossibility of magnifying the fixed stars, together with that of their affording no sensible parallax, has hitherto put it out of our power to do otherwise than surmise their distances. The only use of the telescope, with reference to the fixed stars, is to penetrate more and more into space, and bring out, as it were, still greater numbers of them; so that the quantity of them seems infinite: for they multiply and spring forth, as optical aid is increased. Hence two things are clear: first, that what we call *magnitude* is only apparent, being referred to the power of the eye and telescope; secondly, that magnitude depends upon distance, size, or actual quantity of light, each or all combined.

About 50,000 stars have been catalogued; that is, their celestial latitudes and longitudes are entered, just in the same way as the position of a place on the Earth's surface. It is observable, however, that a different mode of proceeding is here adopted from that which is employed in terrestrial measurements. We have stated that the ecliptic is the path in the heavens, in which the Earth moves round the Sun, or in which the Sun appears to move round the Earth. This circle in the heavens is the place from which celestial lati-

tudes are measured, in the same way as the Earth's equator is the beginning of terrestrial latitude. The positions of the stars are referred to this circle by such kinds of expressions as are used with respect to places on the Earth;—that is, a star being north or south of this line, has such or such latitude. As terrestrial longitude is measured on the circle which forms the 0, or zero of latitude; so, in like manner, is celestial longitude reckoned on the ecliptic, which is the 0, or zero of celestial latitude. But a point of commencement is necessary here, as well as on the Earth's surface; and the point chosen, is the *vernal equinox*, or one of the points in which the celestial equator cuts the ecliptic:—a point which, as we have said before, is called the first point of Aries. From this point then, the longitudes of the stars are reckoned; and when the latitude is previously known, we can designate the position of any star in the heavens, by this double mode of comparing its position with regard to the ecliptic.

For some astronomical purposes, it is deemed more desirable to refer the position of a heavenly body to the celestial equator, instead of the ecliptic. The celestial equator is sometimes termed the *equinoctial*, from the circumstance, that, when the Sun appears in it, the days and nights are equal all over the world; and it is a circle supposed to be formed, as we said before, by the extension of the Earth's equator to the concave of the heavens. The distance from the celestial equator to the pole-star, is supposed, as on the terrestrial globe, to be divided into 90°; and, according as any heavenly body is situated north or south of the equinoctial, it is said to have a north or south *declination*. The east or west position of the heavenly body, considered with refer-

ence to the equinoctial, differs from longitude as reckoned on the ecliptic, in two ways: 1st. it is called *right ascension,* and not longitude: 2nd. it is usually reckoned in hours, instead of in degrees. The point from which the right ascension is reckoned, is the same as with the longitude; viz., the first point of Aries: so that, if the Sun be exactly at the opposite part of the heavens from the first point of Aries, he is said to have twelve hours of right ascension; twelve hours being equivalent to 180°: such a position takes place on the 21st of September, when the Sun enters Libra, which is diametrically opposite to the sign Aries.

By these two methods, the position of any heavenly body, whether Sun, Moon, Planet, Comet, or Fixed Star, can be determined, and described with as much exactness as the position of any place on the Earth's surface. The situation of any heavenly body, with respect to a particular place on the Earth, is determined by its altitude and azimuth; but its situation, in regard to the heavens in general, is determined by its declination and right ascension, or by its latitude and longitude.

Besides the classification of the fixed stars into constellations, it is customary, in order to distinguish one star from another, in any one constellation, to attach letters, one to each star, by which they shall be known. The letters of the Greek alphabet are used for this purpose; and, when they are all exhausted, numerals are employed, at least for the stars of small visible magnitudes. Thus, there is a star marked γ in the constellation, called Draco, or the Dragon, near the North Pole. This star comes once every day, almost precisely into the *zenith* of London, or *immediately overhead:* this star

has of late years engaged much of the attention of astronomers, with the hope of obtaining, by its means, some indications of the distance at which the stars are situated from the Earth. For this purpose, there was erected at Greenwich, about five years ago, a zenith-micrometer. A micrometer, as the word by its derivation implies, is an astronomical instrument for *measuring small* angular distances. The object of this instrument, which was twenty-five feet long, was to measure the angular meridian-distance from the zenith of the star γ Draconis, at different times of the year, or at different parts of the Earth's orbit, which is the same thing. A variation in this angular distance at the lapse of six months, would have proved an annual *parallax**:—but this the observers at Greenwich failed to discover, and the subject remains as it was before. If the observers had succeeded in detecting a parallax of only one second of a degree, it could have been proved by calculation that this, or any other of the fixed stars, could not have been distant from the Earth, less than 19 billions of miles.

In order, therefore, that astronomers may know this star when spoken of, it is called γ *Draconis*, that is, the star in the constellation of the *Dragon*, which is marked

* The question of *parallax* was first studied by Hipparchus, who flourished about 150, B. C. He was first led to it by observing the different *apparent* positions of a tree which he saw on a plain. He also first discovered that the interval between the vernal and the autumnal equinox is seven days longer than between the autumnal and vernal, occasioned by the eccentricity of the Earth's orbit. He divided the heavens into constellations. He taught the use of longitude and latitude, afterwards employed by Ptolemy. He likewise laid the first foundations of trigonometry, and made a calculation of eclipses for 600 years.

by the Greek letter γ. Some of the stars which are distinguished for their superior brilliancy, have particular names attached to them;—such as Sirius, in the right shoulder of the constellation Orion; Rigel, in his left foot; Arcturus, &c.

The principal fixed stars, which lie within a convenient distance of the Moon's path, are used for taking *Lunar distances*, in order to enable mariners to deduce their longitude. The distances of particular stars from the Moon, at certain regularly recurring times, when the Moon is visible, are calculated at Greenwich, and set down for some years in advance according to Greenwich time. As the motion of the Moon is quicker than that of any other heavenly body as seen from the Earth, these lunar distances soon change. If then a person on the ocean wishes to know his longitude, and he finds, for instance, that on such a day and hour, according to the *Nautical Almanack*, such a particular star is so many degrees distant from the Moon, but that this lunar distance occurs, as seen from the ship, an hour sooner than the Greenwich time:—in this case, his longitude is 15° W. If the recorded distance had occurred an hour later, his longitude would have been 15° E.

The stars beyond the 7th magnitude are called *telescopic* stars. Those, which are visible to the naked eye at any one time, are supposed not to exceed 2000, notwithstanding the countless assemblage which appears to be present. This results from a sort of optical delusion, whereby the eye is disconcerted by the apparent want of order; but, with the telescope, Sir William Herschel computed that a small portion of the heavens, not exceeding 15° in length, by 2° in breadth, exhibited not less than 50,000 stars, from which it has been cal-

culated that the same instrument would make visible in the whole starry sphere, not less than 75 millions of stars! The mind shrinks within itself at the contemplation of such a vast array,—and still more, when it is considered that this number is limited by the imperfection of human contrivances; for there can be no doubt, that, if our telescopes were more powerful, the number of visible stars would be greatly increased. This observation may refer to that thin gauzy band of light, which seems to surround the dome of the heavens on a clear evening, when the Moon is absent. It has the name of the *Galaxy*, or *Milky way*. By the power of modern instruments this has been shown to be a vast congregation of stars so small, or so far off, that to an observer on our Earth they present only, by their association, a dim zone of light. The elder Herschel observed about 600 stars in his telescope at the same time, and they continued as numerous for a quarter of an hour. He reckoned up in one portion of the Milky way, about 250,000 stars.

The stars are always spoken of as being *fixed;* and if we regulate our expressions by the analogy of general movements, they are certainly fixed; but astronomers have of late years seen reason to believe that a very minute motion may be detected in some stars; that is, that a certain group of stars does not present the same relative distances between the stars of which it is formed at one time, as at another. These quantities of motion, or of difference, are, however, so inconceivably small, that they belong to the refinements of astronomy, and need not be discussed here.

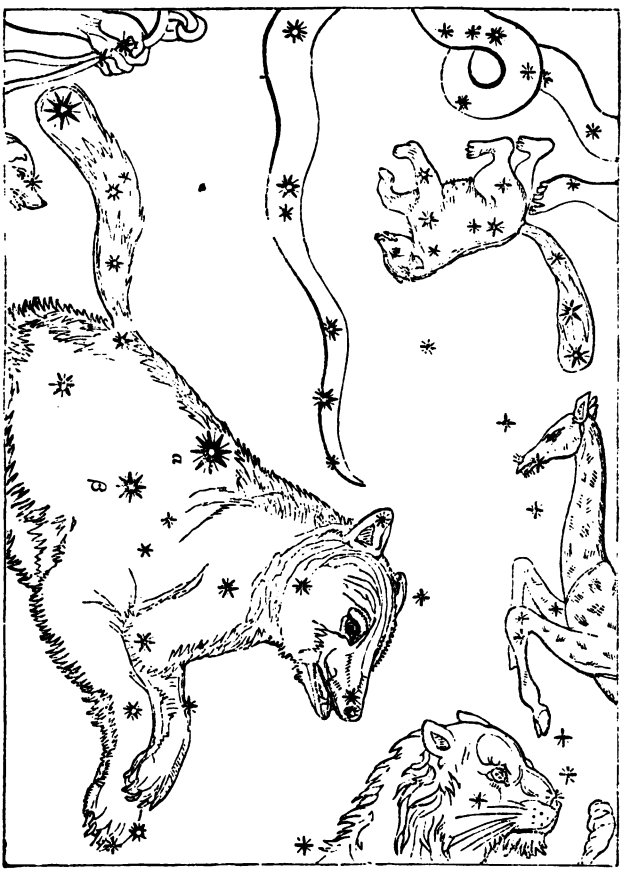
But we have now to notice a very remarkable circumstance, which seems to afford evidence that the

stars are luminaries like our Sun, and have planets revolving round them; that each one

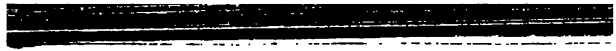
> Informs a system in the boundless space,
> And fills with glory its ap pointed place.

When the stars are observed with close attention by means of a good telescope, many of them are found to be *double*; that is, to consist of two smaller stars, the dark division between them being too faint to be distinguished in an ordinary observation. In some instances, this may occur from one star being almost directly behind another; and though at an immense distance off from the first, yet seeming to our vision to lie in the same line; but, in other instances, it is found that one star revolves round the other, or the two revolve round some point situated between them. Very little was known on this subject until of late years, when Sir William Herschel, and afterwards Sir J. South and Sir John Herschel, distinctly showed that such a revolving motion was perceptible: at one time the satellite, or smaller of the two stars, would disappear, as if it had passed round behind the other in the course of its motion, just as Jupiter or Venus is sometimes invisible to us, on account of being on the opposite side of the Sun; or the satellites of Jupiter, by passing round the body of that planet. There is a double star, marked ξ in the right hind foot of the constellation called the *Great Bear*, in which the two component stars revolve round each other in about 60 years; so that nearly a whole circuit has been performed since its discovery in 1781. About 3000 of these double stars have been observed, and formed into a catalogue, in which their positions, with respect to latitude and longitude, and the relative positions of the two component stars of each,

Fig. 48.



THE CONSTELLATION OF THE GREAT AND LITTLE BEARS.



are entered with great exactness, in order that future observers may have the means of comparing the different appearances of these stars at different times.

In about fifty instances the stars have been found to be *triple*, or three stars revolving about a common centre. In some cases *four*, and even *five* stars have been detected revolving in this way; thus furnishing a further analogy to the composition and relative action of the different bodies which form our own system.

Another peculiar appearance which presents itself in the heavens are *nebulæ*, which are dim, whitish, *cloudy* patches, observable at some parts of the firmament. When examined with a powerful telescope, many of them are found to consist of clusters of very minute stars, so thickly studded together, that the light of all is combined into one faint sheet, as it were, of light, and thus presents the thinly-luminous appearance by which the nebulæ are distinguished. In other instances, however, the most powerful telescopes have been unable to separate the nebulæ into stars, or clusters of stars; but the whole maintains the same thin and milky appearance, whether seen with or without the aid of the telescope. In this latter case, it is supposed that the nebulæ are formed of clusters of stars as in the former case; but that they are so extremely distant, that the light they shed is unable to reach the eye, except in a combined form from the whole of the nebulæ taken together. Some of these nebulæ appear like a faint luminous atmosphere surrounding a star of some brilliancy. Sir William Herschel has left descriptions of about 2000 nebulæ, which he observed at different parts of the heavens.

It is considered to be probable, that the fixed stars

are SUNS, having planets revolving round them in the immensity of space; and it has been observed, that there are stars of all the colours of the spectrum. The stars are usually discovered by the eye from planets by their twinkling, which arises, probably, from some unequal refraction of light, in consequence of the distance of its path. There are stars seen now in the heavens which did not appear formerly, and many have disappeared, which are recorded as shining with brilliancy in former ages. Some stars appear and disappear alternately; of others the magnitude and brilliancy are variable.

When we come, therefore, to consider the vast distance of the fixed stars with the progressive, though rapid, motion of light, it is quite clear that many stars which *now* appear shining, may have been annihilated long ago, and that the last beams which they shed may take years in reaching this earth. If our Sun were suddenly extinguished, we should not know it until eight minutes after the extinction; and if it were suddenly rekindled, its rays would take eight minutes in order to reach us.

> How distant some of the nocturnal suns!
> So distant, says the sage, 'twere not absurd
> To doubt, if beams, set out at Nature's birth,
> Are yet arrived at this our foreign world;
> Yet nothing half so rapid as their flight.—YOUNG.

In order to acquire a knowledge of the aspect of the heavens, it is necessary for those who live in the northern hemisphere to direct their attention to the *polar star*. This is one of the chief stars of the constellation termed the *Little Bear*, (see fig. 48,) at the tip of the tail of which it is situated, and is of the

second magnitude. It is about $1\frac{1}{2}°$ from the pole; and, saving the small circle which it thus describes, it is always in the same position at every hour of the day and night, and at every season of the year. To the point, from which this star is about $1\frac{1}{2}°$ distant, there is, southward, a corresponding point, round which *two* points the concave sphere of the heavens, studded with stars, seems to turn; this being, in reality, due to the diurnal motion of the earth on its axis. The stars round about these two points are called *circumpolar* stars, as revolving constantly about the poles; and those which, in consequence, never set to our and more northern latitudes, are termed stars of *perpetual apparition*, because they are constantly above the horizon. The stars α and β, in the Great Bear (fig. 48), are called the *Pointers*, because, if we follow them, they lead almost in a right line to the Pole-Star:—they serve, therefore, to *point out* this star. In this cut we have, apart from the drawings of animals, the seven principal stars in each of the Bears; E D being those of the Little Bear, and C A B those of the Great Bear. D is the Pole-star, and is nearly in a line with A B, the pointers.

Fig. 49.

After the Great and Little Bears, which are very conspicuous, and easy to remember, the other principal constellations may be readily recognised. Nearly surrounding the Little Bear is the constellation Draco. In the upper corner of the right hand, appear parts of the constellations Lynx and Camelopardalus: and at the lower corner of the left hand, part of the constellation Boötes.

The constellation Orion, the Pleiades, and the star Arcturus, of the first magnitude, are known in Scripture. The term *Mazzaroth*, used in the book of Job, xxxviii. 32, is supposed to imply the *constellations of the Zodiac*, which are thought to be meant by Joseph, when he spoke of the sun, moon, and eleven stars, bowing down to pay him homage, himself being the twelfth.—Gen. xxxvii. 9. But the science of astronomy was not much encouraged at any time among the Jewish people, lest they might the more easily be allured to join in the idolatries of the neighbouring nations, all of whom eagerly gave themselves up to the worship of the "heavenly host."

We ought not to omit to mention, that in the Southern Hemisphere is the constellation called the CROSS, which, from the disposition of the principal stars, is a type of that sacred emblem; it is almost entirely enveloped by the southern part of the milky way, as shown in the figure. This is, perhaps, one of the justest configurations that astronomers have ever made, and is thus alluded to by the poet Rogers, who also speaks of the superior radiance of the stars in the heavens below the Line:—

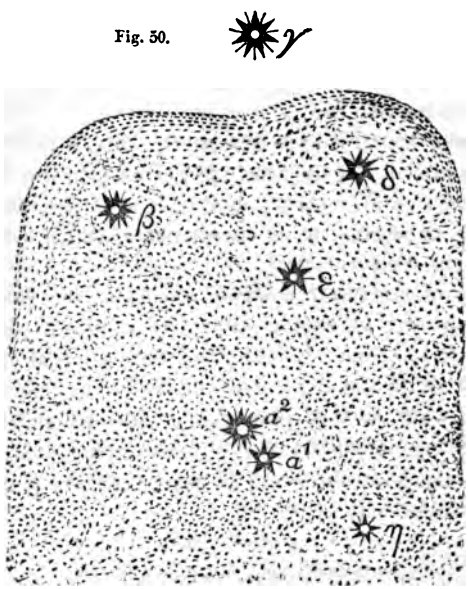
> . . . . . And now in opener skies
> Stars yet unnamed of purer radiance rise!

Stars, milder suns, that love a shade to cast,
And on the bright wave fling the trembling mast!
Another firmament! the orbs that roll,
Singly or clustering, round the southern pole!
Nor yet the four that glorify the night—
Ah, how forget, when to my ravished sight
The Cross shone forth in everlasting light!

The mariners in the *Lusiad* also thus apostrophize his constellation:—

While nightly thus the lonely seas we brave,
Another Pole-star rises o'er the wave;
Full to the south a shining Cross appears;
Our heaving breasts the blissful omen cheers.
Seven radiant stars compose the hallowed sign,
That rose still higher o'er the wavy brine.

Fig. 50.



Owing to the annual motion of the Earth, the Sun appears to move among the zodiacal constellations from West to East. Hence it is that, while the whole dome of the fixed stars seems to move round the Earth from East to West, in consequence of the Earth's diurnal motion, the stars appear to rise about 3′ 56″ sooner every evening, and thus seem to gain nearly one whole revolution over the Sun in a twelvemonth, which is due to the Sun having finished its circular course through the ecliptic. The Earth completes one revolution on its axis in twenty-three hours and fifty-six minutes, which is termed a *sidereal* day, being the time which elapses from any star coming upon the meridian till its arriving there again; this would, therefore, be the length of the day, were the Earth stationary; but, as we said before in other words, the Earth advances nearly one degree in its orbit in one day, or the Sun seems to move this space in the ecliptic.

When the Moon, in her passage round the Earth, passes over any of the fixed stars or planets, she is said to *occult*, or *hide* them; and such a phenomenon is termed an *occultation*, an observation of which is useful in determining longitude.

One of the latest opinions respecting the cause of *shooting stars* is, that they are fragments of planets, which in the course of their revolutions come, at certain times, within visible range of the Earth; and that the Earth, when at that part of her orbit where she is brought by the middle of November in each year, is in that point of space, which is nearest to the places of such revolutions.

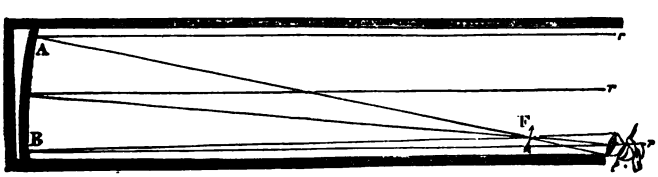
CHAPTER XIII.

THE REFLECTING TELESCOPE. HERSCHEL'S DISCOVERIES THEREWITH. THE TELESCOPE MADE BY NEWTON. CONCLUSION. CONTEMPLATION OF THE UNIVERSE.

HAVING had occasion, more than once, to refer to the discoveries made by Sir William Herschel, in the celestial regions, we cannot altogether dismiss the subject, without describing the stupendous and wonderful instrument, which he himself constructed, and with which he enriched the modern state of astronomical knowledge. The magnifying powers of this instrument exceeded all that had ever been known, previously or since.

We will suppose the reader to be at least moderately acquainted with the principles and use of the common refracting telescope: he will therefore observe that the subjoined figure affords a representation of Herschel's REFLECTING Telescope:—

Fig. 51.



Let us suppose A B to be a concave reflector, and *r* A, *r* B to be rays proceeding from a distant object, such as a star. The reflector A B is not placed symmetrically across the tube, but has such a degree of inclina-

tion given to it, as will bring the rays to a focus at i near the margin of the mouth of the tube. The eye c the observer being now placed at that point, he will se the image formed by the focalization of the rays. Th object to be obtained in thus bringing the rays to focus at the margin of the tube, instead of at the centr of its diameter, is, that the body and head of th observer may intercept as few rays as possible; for i will be seen that it is quite impossible for him to lool into the tube, without obstructing the passage of som of the light proceeding from the object. But this ob struction is thus limited as much as possible.

This telescope was begun by Sir William in the yea 1785, by the pecuniary aid afforded to him by Kin George the Third, who was his patron. Hersche superintended the whole of the construction of i himself; and he had as many as forty workmen em ployed upon it at once. In February, 1787, he hac the first view through this telescope, although it wa not completely finished till August, 1789.

The great reflector, A B, was forty-eight inches in diameter of polished surface. A speaking-trumpet wa fitted to the side of the telescope, for the observer tc communicate the result of his observations to an assistant below, who was stationed in a small house, and provided with various instruments for measuring time, the positions of the stars, &c. This vast tube was moved about in any direction, by means of a large and complicated apparatus. The eye-pieces, through which the observer viewed the reflected image of an object, were held at the mouth of the tube by a sliding appa- ratus, by which the attention could be directed to any particular part of the speculum, A B.

The frame-work of this instrument having been found to be greatly decayed, after it had remained thirty years in its place, the whole was taken down and replaced by a smaller one, on the like construction, by Herschel's son, one of the most distinguished astronomers of modern days.

No sooner had the great telescope been erected by Sir William Herschel, than he began an important series of discoveries by its means. He discovered the sixth satellite of Saturn (five only having been previously known,) on the day that this instrument was completed. He had already discovered the planet Uranus, as before related; a circumstance, such as had never taken place since the days of the most ancient nations of the world. Moreover, by the aid of the new telescope, Herschel distinguished, one by one, six luminaries revolving about it; as also the seventh satellite of Saturn. The same able astronomer also discovered that the ring which surrounds the planet Saturn, is not only divided into concentric belts by a dark circle, as had been already noticed by Cassini, but that the ring likewise revolved about the body of the planet.

The art of constructing telescopes, has, like all other arts, advanced by degrees to its present state of comparative perfection. In the case of the reflecting telescope, which is, for astronomical purposes, a vast and efficacious improvement upon the former mode of using these instruments, there have been several sorts at different times constructed. These go by the names of the Newtonian, the Gregorian, the Cassegrainian, Brewster's, and Herschel's. The principle of them all is the same: but the circumstances in which they differ from one another, are chiefly in the manner in

which the image of an object is conveyed to the eye of an observer. In every instance, rays of light from the celestial body pass into the tube of the telescope (which is *open* at the end *nearest* to the object,) and fall upon the surface of the speculum at the bottom of the tube, as shown in the preceding figure. These rays, after reflection from the surface of the speculum, meet again in a focus near the upper end of the tube, and there form a small image of the object; which image is conveyed to the eye of the observer by one of the five different contrivances, which thus form the points of difference between the various reflecting telescopes.

Of Herschel's telescope we have already spoken. Into the merits of the telescopes of Gregory, Cassegrain, and Brewster, it is not necessary here to enter; but we cannot refrain from giving a few brief notices of Newton's genius as developed in the construction of a reflecting telescope, for exploring those celestial tracts, which his skill and perspicacity were employed in reducing to order and harmony, for the better understanding of those who were to come after him.

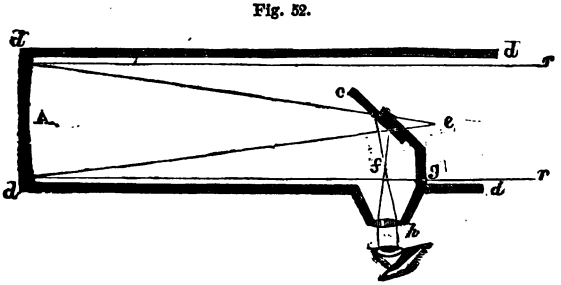
It has been well remarked of Sir Isaac Newton, that it was his brilliant fortune to improve almost every subject to which he directed his gigantic mind. He was the first to put in practice the idea of employing reflected light for the formation of the image in a telescope. Vast and splendid as were the theoretical and mathematical powers of his mind, yet he did not disdain to construct with his own hands the instrument which his inductive reasoning told him would serve the purpose of a telescope. He, accordingly, made the first reflecting telescope which the world ever saw, and which is now in the museum of the Royal Society of

London:—a precious memento of the ingenuity of one whose name will never die.

We are told that Newton's first reflecting telescope was $6\frac{1}{4}$ inches long, and had an aperture of about $1\frac{1}{8}$ inches. The eye-glass was inserted in the side of the tube, and was one-sixth of an inch deep. This instrument, although so small, magnified thirty-five times, and enabled Newton to see the crescent-form of Venus, and Jupiter's satellites. He then made another, which was $2\frac{1}{3}$ inches in diameter, and therefore gave a larger reflecting surface to the speculum at the bottom of the tube.

The following figure shows the construction of the Newtonian reflecting telescope.

Fig. 52.



A is the speculum, or reflecting surface, formed of polished metal, either spherically or parabolically curved:—the latter is more correct, but the former is more easy to construct. This speculum, as we saw in the case of Herschel's telescope, is placed at the end of the tube *d d d d*, and has such a degree of curvature, that the rays *r d*, *r d*, from any celestial object, will,

after reflection be conveyed to a focus at *e*, near the mouth of the tube. But, before they reach this point, their progress is arrested by a plane mirror, *c*, so placed as to make an angle of 45° both with the length and with the diameter of the tube. This plane mirror is held in its place by an arm or bracket, *g*, fitted to the side of the tube, but, at the same time, capable of sliding along it, in order that the distance between the two reflectors may be increased or diminished at pleasure. Let us now suppose that rays from a celestial object are entering the tube, and that they are reflected from the surface of the speculum A: instead of meeting at *e*, they are reflected a second time, from the small plane mirror *c*, and cross each other at the point *f*, at which point of intersection an image of the object is formed. At this part of the process is the following adaptation:—a convex lens is fitted into a socket *h*, the focal power of which lens is such, that the image is in that focus, and the magnitude of the image is increased.

Many disadvantages resulted from the necessity for the observer looking in at the *side* of the tube; and inconvenience manifestly results from looking down the mouth of the tube. Those who have attempted to construct reflecting telescopes, have always had in view the removal or diminution of the difficulties mentioned before. Complete success, without loss of light, has not, however, attended their efforts.

From the time when Galileo made his telescope, which was of the common refracting sort, with eye-pieces, one at each end of a tube, to the construction of Herschel's great reflecting telescope, a period of nearly 200 years, the knowledge of the heavens rapidly pro-

gressed. The construction of the Newtonian telescope was an event mid-way; but the further extent of our knowledge of "the argent fields above," will have to depend mainly on the further improvement of our telescopes.

In concluding this part of the subject of ASTRONOMY, we cannot do better than use the thoughtful and eloquent words of Chalmers:—

"The first thing which strikes a scientific observer of the fixed stars, is their immeasurable distance. If the whole planetary system were lighted up into a globe of fire, it would exceed, by many millions of times, the magnitude of this world, and yet only appear a small lucid point from the nearest of them. If a body were projected from the Sun, with the velocity of a cannon-ball, it would take hundreds of thousands of years before it described that mighty interval which separates the nearest of the fixed stars from our sun and from our system. If this Earth, which moves at more than the inconceivable velocity of a million and a half miles a day, were to be hurried from its orbit, and to take the same rapid flight over this immense tract, it would not have arrived at the termination of its journey after taking all the time which has elapsed since the creation of the world. These are great numbers, and great calculations; and the mind feels its own impotency in attempting to grasp them. We can state them in words. We can exhibit them in figures. We can demonstrate them by the powers of a most rigid

and infallible geometry. But, no human fancy can summon up a lively or an adequate conception—can roam in its ideal flight over this immeasurable largeness—can take in this mighty space in all its grandeur, and in all its immensity—can sweep the outer boundaries of such a creation—or lift itself up to the majesty of that great and invisible arm on which all is suspended.

"But what can those stars be which are seated so far beyond the limits of our planetary system! They must be masses of immense magnitude, or they could not be seen at the distance of place which they occupy. The light which they give must proceed from themselves; for the feeble reflection of light from some other quarter, would not carry through such mighty tracts to the eye of an observer. A body may be visible in two ways. It may be visible from its own light, as the flame of a candle, or the brightness of a fire, or the brilliancy of yonder glorious Sun, which lightens all below, and is the lamp of the world. Or it may be visible from the light which falls upon it, as the body which receives its light from a taper, or the whole assemblage of objects on the surface of the Earth, which appear only when the light of day rests upon them—or the Moon, which, in that part of it that is towards the Sun, gives out a silvery whiteness to the eye of the observer, while the other part forms a black and invisible space in the firmament—or as the planets, which shine only because the Sun shines upon them; and which, each of them, present the appearance of a dark spot on the side that is turned away from it. Now apply this question to the fixed stars. Are they luminous of themselves, or

do they derive their light from the Sun, like the bodies of our planetary system? Think of their immense distance, and the solution of this question becomes evident. The Sun, like any other body, must dwindle into a less apparent magnitude as you retire from it. At the prodigious distance even of the very nearest of the fixed stars, it must have shrunk into a small indivisible point. In short, it must have become a star itself, and could shed no more light than a single individual of those glimmering myriads, the whole assemblage of which cannot dissipate, and can scarcely alleviate, the midnight darkness of our world. These stars are visible, not because the Sun shines upon them, but because they shine of themselves, because they are so many luminous bodies scattered over the tracts of immensity; in a word, because they are so many suns, each throned in centre of his own dominions, and pouring a flood of light over his own portion of these unlimitable regions.

"At such an immense distance for observation, it is not to be supposed that we can collect many points of resemblance between the fixed stars and the solar star, which forms the centre of our planetary system. There is one point of resemblance, however, which has not escaped the penetration of our astronomers. We know that our Sun turns round upon himself in a regular period of time. We also know that there are dark spots scattered over his surface, which, though invisible to the naked eye, are perfectly noticeable by our instruments. If these spots existed in greater quantity upon one side than upon another, it would have the general effect of making that side darker; and the revolution of the Sun must, in such a case, give us a brighter and

a fainter side, by regular alternations. Now, there are some of the fixed stars which present this appearance. They present us with periodical variations of light. From the splendour of a star of the first or second magnitude, they fade away into some of the inferior magnitudes; and one, by becoming invisible, might give reason to apprehend that we had lost him altogether; but we can still recognise him by the telescope, till at length he re-appears in his own place, and, after a regular lapse of so many days and hours, recovers his original brightness. Now, the fair inference from this is, that the fixed stars, as they resemble our Sun, in being so many luminous masses, of immense magnitude, they resemble him in this also, that each of them turns round upon his own axis; so that, if any of them should have an inequality in the brightness of their sides, this revolution is rendered evident, by the regular variations in the degree of light which it undergoes.

"Shall we say, then, of these vast luminaries, that they were created in vain? Were they called into existence for no other purpose than to throw a tide of useless splendour over the solitudes of immensity? Our Sun is only one of those luminaries, and we know that he has worlds in his train. Why should we strip the rest of this princely attendance? Why may not each of them be the centre of his own system, and give light to his own worlds? It is true that we see them not; but could the eye of man take its flight into those distant regions, it would lose sight of our little world before it reached the outer limits of our system—the greater planets would disappear in their turn—before it had described a

small portion of that abyss which separates us from the fixed stars, the Sun would decline into a little spot, and all its splendid retinue of worlds be lost in the obscurity of distance—he would at last shrink into a small indivisible atom, and all that could be seen of this magnificent system, would be reduced to the glimmering of a little star. Why resist any longer the grand and interesting conclusion? Each of these stars may be the token of a system as vast and as splendid as the one which we inhabit. Worlds roll in these distant regions; and these worlds must be the mansions of life and of intelligence. In yon gilded canopy of heaven, we see the broad aspect of the universe, where each shining point presents us with a Sun, and each Sun with a system of worlds—where the Divinity reigns in all the grandeur of His attributes—where He peoples immensity with His wonders; and travels in the greatness of His strength, through the dominions of one vast and unlimited monarchy.

"The contemplation has no limits. If we ask the number of suns and of systems, the unassisted eye of man can take in a thousand, and the best telescope which the genius of man has constructed, can take in eighty millions. But why subject the dominions of the universe to the eye of man, or to the powers of his genius? Fancy may take its flight far beyond the ken of eye or of telescope. It may expatiate in the outer regions of all that is visible—and shall we have the boldness to say, that there is nothing there?—that the wonders of the Almighty are at an end, because we can no longer trace His footsteps?—that His omnipotence is exhausted because human art can no longer follow Him?—that the creative energy of God has sunk into

repose, because the imagination is enfeebled by the magnitude of its efforts, and can keep no longer on the wing through those mighty tracts, which shoot far beyond what eye hath seen, or the heart of man hath conceived: which sweep endlessly along, and merge into an awful and mysterious infinity?"

Leaving now the consideration of the heavens, and all that is therein contained,—as far as mere wonder and admiration are concerned,—let us pass on to observe the use which man makes, under Providence, of his knowledge of the celestial bodies and their motions; remembering that, next to the faithfulness of their great Author, the motions of those bodies are more faithful and regular than aught else, which comes under man's experience.

CHAPTER XIV.

TIME. ALMANAC AND CALENDAR. CORRECTIONS OF THE CALENDAR. COLUMNS OF AN ALMANAC. COMMON NOTES OF THE ALMANAC.

THE especial use of astronomical science, in reference to the common affairs of life, is to regulate the order of TIME. It is only within the last few hundred years that astronomy has been cultivated with such improved means, as to allow of anything like precision and uniformity in measuring off successive portions of man's brief existence here. But the necessity and importance of doing this are so obvious, that the wisest and most skilful of mankind, in different ages and countries, have given their attention, to determine and to compare standards of time, which shall be of universal reference and applicability to the whole human race. How far, and by what means, they effected this object, in an *elementary* way, we will endeavour to explain, as far as the question is comprehended within the limits of astronomy.

The terms *Almanac* and *Calendar* may be considered as synonymous; but, if any distinction may be admitted, the former implies an annual publication, comprising the Calendar for the year ensuing, as also all other information relating to the actions of men in the civil affairs of life, which it is necessary to know and act up to, in order to discharge our duties as good subjects, good neighbours, and "citizens of the world."

But the Calendar seems now to be understood to be a methodical digest of the ensuing year into its months

and days, with all the information relating to such individual months and days, particularly with respect to celestial phenomena; such as the motions of the Sun, Moon, and planets.

Now, whether we call the book of which we speak, an "Almanac" or a "Calendar," our observations can only apply to that part of it which furnishes a digest of the year, with reference to the motions of the celestial bodies*. We shall, therefore, treat of the subject, first, with reference to the ALMANAC or CALENDAR; and secondly, by explaining the common NOTES of the Calendar.

I. The word "Almanac" has given rise to much discussion among philologists, or *lovers of reading:* but it seems to imply, according to its derivation from the Arabic, the book used for *reckoning* or *counting.*

The CALENDAR is an adjustment of time, according to rule, for the use of society. The term "Calendar" is derived from an old classic word, implying to *call,* from the circumstance of the Pontifex Maximus, the head of the ancient priests, being used to *proclaim,* on the first day of the month, the appearance of the new moon, and the festivals to be observed throughout the month.

One column in an Almanac is frequently the days of the year, and we number them from the 1st of January onward to the 31st of December; so that the last-mentioned day is the 365th of the year. There are not many persons now living who remember when the year commenced on the 25th of March: yet such was the

* Such a work, when intended chiefly for the use of persons conversant in astronomy, is called an *Ephemeris.* See p. 79.

ase, until the year 1752. Many inconveniences resulted from commencing the year near the end of a month, and it was resolved that from that date the year should commence on the first day of a month; the month chosen, *i. e.* January, being the nearest to Midwinter. This plan has been acted on to the present time, and will probably continue for ages to come.

In the early stages of society, the progress of time was estimated by the courses of the Sun and Moon; the former marking out years, seasons, and days; and the latter months and weeks.

But, of the several divisions of time, it has been found most difficult to determine with accuracy the *month* and the *year;* since the revolution of neither the Sun nor the Moon is completed in an exact number of days. To reconcile the revolutions of the Sun and Moon with the common account of time, and to make them agree with each other, was the object held in view upon reforming the Calendar on several remarkable occasions.

Therefore, if we look into an Almanac for Leap-year, —1840, for instance,—we find that there are 366 days in that year; so that the year is then positively longer than ordinary years. The cause of this we must explain. Until the time of Julius Cæsar, the year was almost generally reckoned to contain 365 days exactly; so that after the lapse of 365 days from the beginning of one year, the following year commenced. But this is not quite correct: a year is really equal to nearly $365\frac{1}{4}$ days. For centuries, therefore, the year had been reckoned too short; the consequence of which was, that the year was, in Julius Cæsar's time, made to

begin ninety days too soon, owing to the accumulation of error. Being, therefore, convinced by the Greek astronomer, Sosigenes, that the year then employed was too short, and that it could never be properly settled but by referring it to the (apparent) annual revolution of the Sun, and finding that about ninety days had been lost by the old reckoning, he made the first Julian year to consist of 444 days, which was in consequence called "the year of confusion." This year was thus made to terminate at the proper season. The following years, with the months, were then adjusted nearly as they are at present; and, as the year was from that time made to consist of 365¼ days, a day was inserted every fourth year between the sixth and fifth of the calends of March (which days answer to the 24th and 25th of February); so that, the sixth day of the calends of March being repeated, there were accounted to be *two sixth-days* of the calends of March, and the day thus inserted was named *bis-sextus dies*, or the double-sixth day; whence we call Leap-year, in which this addition is made, BISSEXTILE.

But, as the year does not consist of quite 365¼ days, it was found, in the 16th century after Christ, that the course of the civil year was ten days in advance of the course of the Sun. The Calendar was therefore again corrected by Pope Gregory XIII., A. D. 1582. This, which is called the New Style, was adopted in England, A. D. 1752. The regulations assumed in this second reformation of the Calendar, are such as, reckoning from the 16th century, will make the civil year and the course of the Sun to differ, after the lapse of 4000 years, only to the amount of *one day*.

The error had amounted, in 1752, to about eleven

days; so eleven days were subtracted from that year, leaving it, in length, only 354 days. In Hogarth's prints of the "Election," one of the electors has a paper with the inscription, "Give us back our eleven days!" This alludes to a popular clamour among the ignorant of that time, that the government had robbed the people of eleven days. The day after the 2nd of September was made the 14th.

The column of an Almanac devoted to the *day of the month* is in many respects curious. The word *month* is derived, as we observed before, from the word *moon;* and a month is *nearly* equal in length to the time that the Moon takes in going through all her changes. But it is not exactly so: if we look at an Almanac, we see that the calendar month is longer than the lunar month. In the early stages of society, and in uncivilized countries at the present day, the time from new moon to new moon forms a very convenient and distinctly marked period, for the measure of long intervals. But it happens that twelve moons, or lunar months, are not quite so long as a year, and that thirteen are longer; so that, in order to make the beginning of a year correspond with the beginning of a month, we have to resort to artifice. A year contains eleven days over and above twelve lunations, or lunar months; so that, by adding to the lengths of the months,—making some to contain thirty, others thirty-one days, &c., (a lunar month containing twenty-nine and a half,) we manage to make the year contain exactly twelve *calendar* months. It must be owned that this adjustment is much more clumsy than that which relates to the length of the year.

The column of *days of the week* relates to a division

of time which has been used from the very earliest period. The earliest people on the Earth's surface had a *sabbath*, or sacred day, being every seventh day, which was ordained by Divine authority to be kept holy, in commemoration of the completion of the great work of creation. The Jews, who have never ceased to exist as a people, however much they have been scattered over the world, have maintained a classification of days into weeks down to our own time, and other nations have followed their example. Another circumstance attending the clustering of days into periods of seven each, is, that a week is very nearly one quarter of a complete lunation; so that full moon is always *about* a fortnight after new moon. As there is one day more than fifty-two weeks in a year, every year begins one day later in the week than the preceding year; and if it be leap-year, it is *two* days later.

The columns for *sun-rising* and *sun-setting* are nearly the same year after year, for any given place, but differ for different places. The reason why the Sun rises on any given day, say Jan. 1st, at the same hour and minute as on the same day of the preceding year, is that, by the corrections to which we before alluded, the length of the civil year is almost exactly equal to that of the astronomical year, and so the Sun is situated, with respect to any given place, exactly the same at the end of the year as he was at the beginning.

If the Earth did not rotate on her axis, we should see the Sun gradually mounting in the heavens from December to June, and descending from June to December; but, as the Earth *is* rotating, the effect produced is, that the Sun rises earlier and sets later every day from December to June, and rises later and sets

earlier every day from June to December; thus producing all the diversity of our seasons, as we before explained. Thus, then, results the variation in the numbers expressing the rising and setting of the Sun in an Almanac.

But why will not a table of rising and setting do for all parts of the world? Why must an Edinburgh Almanac, for instance, totally differ from a London one, in the times specified? This is occasioned by difference of *latitude*. In June, the Sun at Edinburgh rises to a greater height than in December, as is the case in London; but it is *always* at a less height than at London, both in winter and summer, in consequence of Edinburgh being at a greater distance than London from the equator, where the Sun is more immediately over head. This circumstance affects the time of rising and setting; so that a London Almanac is useless with respect to the times of sun-rise and sun-set at Edinburgh.

The time of the Moon's *southing* frequently occupies a column in an Almanac. This expression alludes to the moment in each day when the Moon is south, or on the meridian of the observer; and it varies very rapidly from day to day: the Moon souths on an average fifty minutes later each day. The cause of this is, that the Moon is moving constantly *eastward*, while the Earth is rotating in the same direction; so that the Earth has, as it were, a journey of fifty minutes to perform, before she can again catch the Moon, after having performed one rotation. A table of the Moon's southing for Edinburgh will not differ much from one for London, because Edinburgh is not very far from being due north of London. But, if it were far to the east or west, as at Petersburgh or New York, the same

table of southing would not serve, because the Moon moves a good way eastward, in the interval of her southing at London, and southing at New York, &c.

The *rising and setting* of the *Moon* are also frequently given. These differ greatly day by day in the same Almanac,—their rate of variation is not the same as for southing; and tables arranged for different places show very dissimilar results. The causes for all this are much too complicated to be explained here; but we may mention one or two:—the Moon is constantly moving eastward in the heavens: the rapidity of her motion is continually varying: and she is not moving in the same path as the Sun moves. The latitude and longitude of the observer's position, the place of the Moon in her orbit, the rapidity of her motion, and other particulars, are therefore to be taken into account in computing the rising and setting of the Moon; and this forms altogether a tedious and difficult part of the Almanac-maker's duties.

The *Moon's phases* are given in all Almanacs; that is, as before explained, the times when she is a full Moon, a half Moon, (twice in the month,) and a new or invisible Moon. All these terms relate, not to the actual quantity of light which falls on the Moon from the Sun, but to the portion of the illuminated half of the Moon which happens to be turned towards the Earth; and therefore, in every case, what we call the *age* of the Moon, depends on the position of the Earth with respect to the Sun and Moon.

We may here remark, that the Moon's influence on parts of the human body, as given in some old-fashioned Almanacs, is an entire *fallacy:* it is most untrue and absurd, often indecent, and is a discredit to the age we live in.

Equation of time, as given in Almanacs, is the difference between the time as indicated by a sun-dial, and that indicated by a correct clock. It is occasioned by the circumstance that the Sun, which is the chief agent in forming measures of time, does not appear to move equally fast on all days of the year; so that an hour by a sun-dial, which correctly indicates the Sun's motion, is sometimes longer, and at other times shorter, than an hour indicated by a good clock:—a clock's hours are all equal, but the Sun's hours are not all equal. The equation of time shows how many minutes are to be added to or subtracted from sun-dial time, in order to obtain clock time, or *vice versâ*. The same table of equation of time will serve all over the world.

II. The NOTES usually given at the commencement of an Almanac, were the elements employed in the correction of the Calendar. They are the following; which we proceed briefly to explain:—

1. Golden Number.
2. Epact.
3. Solar Cycle.
4. Sunday Letter.
5. Roman Indiction.
6. Number of Direction.
7. Julian Period.

1. The GOLDEN NUMBER is the number which any given year holds in the Lunar Cycle, which is a period of nineteen years, at the lapse of which the new Moons take place on the same days of the same months respectively, as at the commencement of the Cycle. Therefore, while the Sun performs its annual course nineteen times, those of the Moon amount to two hundred and thirty-five. The importance of this dis-

covery in the regulation of time was held to be so great, that the rule for ascertaining the number of the year in the Lunar Cycle was engraved on a *golden* tablet, and set up in the market-place of Athens. Hence the term GOLDEN Number. The rule is given in the Calendar, which prefaces the Church-Service.

2. The EPACT is the number of days over and above all the complete courses of the Moon, for any number of years, in any part of the Lunar Cycle. Hence, it is the Moon's age at the beginning of any year; that is, the number of days which have elapsed since the last new Moon in the preceding year.

3. The SOLAR CYCLE is a period of twenty-eight years, which, owing to Leap-year, must necessarily pass round, before the days of the month can return respectively to the same days of the week, as at the commencement of the Cycle.

4. The Dominical or SUNDAY LETTER is one of the first seven letters of the Alphabet; which letters are used to denote respectively the days of the week, and one of which letters must of course fall to the Sunday throughout the year. But, owing to Leap-year, their order is every fourth year disturbed; so that the Solar Cycle must pass round, before the letters can fall respectively to the same days of the week. The year 1840 being Leap-year, there are *two* Sunday Letters; the left hand letter is used till the end of February, and the other till the end of the year.

5. ROMAN INDICTION was a period of fifteen years, appointed by the Emperor Constantine, A.D. 312, for the payment of certain taxes from the subjects of the empire.

6. The NUMBER OF DIRECTION. It having been

decided by an assembly of Christian bishops, at the Council of Nice, in Italy, A. D. 325, that EASTER-DAY is always "the first Sunday *after* the Full Moon, which happens upon, or next after, the 21st of March;" it follows that Easter-day cannot take place earlier than the 22nd of March, nor later than the 25th of April; so that from one date to the other (both inclusive) are thirty-five days. The Number of Direction is that day of the thirty-five, on which Easter Sunday falls.

7. The JULIAN PERIOD consists of 7980 years; which is produced by the multiplication into each other of the Solar Cycle, the Lunar Cycle, and the Roman Indiction; ($28 \times 19 \times 15 = 7980$.) This period is reckoned from 709 years before the Creation of the world, when the three cycles are supposed to commence together, which circumstance cannot take place again until the lapse of the entire period, A. D. 3267.

The Roman Indiction and the Julian Period are not now of practical use in the Calendar; but the other observations may assist those who wish to understand the Calendar, which is prefixed to the Church-Service in the Prayer-Book.

HAPTER XV.

ASTRONOMICAL INSTRUMENTS, COMMONLY USED IN THE MEASUREMENT OF TIME. EARLY DIVISIONS OF TIME. SUN-DIAL—HORIZONTAL AND VERTICAL. MERIDIAN-LINE. MOON-DIAL. ASTROLABE. HADLEY'S QUADRANT. ARTIFICIAL HORIZON.

WE come now to consider the elementary instruments used to ascertain, with accuracy, the divisions of time, and to estimate the motions, real or apparent, of such heavenly bodies as gave effect to the instruments in question. We may confine ourselves, therefore, to an examination into the nature and uses of the SUN-DIAL and the QUADRANT; having first taken a cursory view of the early and well-established divisions of time.

In the dawn of society, when man had not yet entered upon that career of activity which the developement of mind, the ties of social life, and the gradual growth of his wants and wishes, rendered necessary, the progress of *time* was not an occurrence of paramount importance to him. The day was quite long enough to enable him to cultivate and gather the produce of the ground, or to hunt and appropriate for purposes of food the animals around him. From these he obtained food and clothing; and thus his wants, limited in extent, were easily supplied.

But when increase of population rendered necessary the search for new regions, and when the mental tastes of men began to multiply the number and variety of their employments, it was found necessary to mark the *course* of TIME; to distinguish those periods of the

year when the fruits of the soil were in a fit state for food; those periods in which the rainy season occurred; and (among those nations which were further removed from the equator), those periods when cold blighted the verdure of the trees and flowers. Thus an observance of annual seasons sprang up, long before anything was known of the astronomical causes of those seasons.

But it was, moreover, necessary to divide the day into smaller portions. Men perceived that night succeeded day with great regularity; and they could not have been long in observing, that when the day-light was shorter in duration, the night was proportionably lengthened; and that, conversely, when in summer the day-light was prolonged, the nights were accordingly shortened—the day and night together forming a period of time (nearly) equal at every part of the year, and in every country. This statement is true, with respect to the countries occupied in the early stages of society; all of which were within a few degrees of the extreme latitudes of the Mediterranean sea: but the inhabitants of those comparatively small portions of land situated at a higher latitude than $66\frac{1}{2}°$, experience no night at all at Midsummer, and they suffer a complete deprivation of day-light at Midwinter. This becomes more marked, as we approach nearer to the poles. As before observed, (Chap. VII.) the Sun does not shine on the North Pole from the twenty-first of September to the twenty-first of March, with a small exception, due to atmospheric refraction, at the limits of that period; but from the twenty-first of March to the twenty-first of September the Sun never sets to the North Pole. *Clouds and fogs* may obscure his rays, but he is con-

stantly above the horizon. It follows from this that there is but one night and one day in a whole year at the North Pole, each having a duration of six months. The same conditions obtain at the South Pole, excepting that the times are reversed; summer, or day, (for in this case these terms are convertible into each other,) occurring at the South Pole, when it is winter, or night, at the North. The uninterrupted depression of the Sun below the horizon at Midwinter, occurs in latitude $66\frac{1}{2}°$ for a period of only three or four days; while, as we have seen, this continued depression lasts for six months at the poles. It necessarily results, that intermediate latitudes experience a Midwinter darkness, increasing in duration as we approach the pole. These nocturnal days, (if we may be allowed the term,) are, for five or six different latitudes, as follows: viz.—

In latitude $66\frac{1}{2}°$	North, from	Dec. 20	to Dec. 23
70	„	Nov. 22	Jan. 20
75	„	Nov. 3	Feb. 7
80	„	Oct. 19	Feb. 22
85	„	Oct. 6	Mar. 7
90 (or at the pole)		Sep. 21	Mar. 21

We must observe, however, that at the limits of each of these periods there is a very long twilight. The Sun is not above the horizon, but he is so nearly on a level with it, that for many successive hours, (and, near the pole, for many successive days,) the light yielded is equivalent to that which just precedes sunrise in our own climate.

This continued absence of the Sun is wholly due to the obliquity of the equator to the ecliptic; that is, the *Earth's* motion round her axis, is not in the same plane

as her motion round the Sun, but is inclined to it at an angle of $23\frac{1}{2}°$, as was explained at page 142.

Such, then, is the case with reference to the regions within the arctic and antarctic circles, which surround the poles; the former the northern, and the latter the southern, at a distance of $23\frac{1}{2}°$. But in the times of the ancient Babylonians and Egyptians, these polar regions were unknown, and consequently there was no deviation from the rule, that the duration of an artificial day (the time that the Sun is above the horizon) added to the following night, made an equal quantity at all times of the year. Subsequent observations have, however, detected a deviation, which comes properly under the subject of Equation of Time, to which we shall allude hereafter.

This period, then, the natural day, or one whole revolution of the Earth with respect to the Sun, the ancients wished to divide into smaller portions, to indicate the times of recurrence of similar employments or ceremonies on each successive day. The boundary of one such portion was the instant that the Sun attained his greatest elevation in the heavens: that moment was exactly midway between the preceding and the following nights. The moment of greatest darkness, or when the Sun has his greatest depression below the horizon, was found to be just half a natural day after his greatest height above it. Thus *midday* and *midnight* formed two convenient boundaries, by which the day could be divided into two equal parts. Those parts were each subdivided into two portions, by noticing the times when the Sun rose in the morning, and set in the evening. In the latitude of Great Britain *considerable* difference is observed in these

hours at different parts of the year; the Sun rising in Midsummer before four o'clock, and in Midwinter not till after eight o'clock: the setting of the Sun being in a corresponding manner variable. But in the countries which were first peopled, such as Mesopotamia, Persia, Egypt, Syria, &c., the hour of sunrise is not subject to so much variation. The length of daylight, therefore, although unequal throughout the year, is not so much so as with us. Thus arose four nearly equidistant points of division: *midnight*, *sunrise*, *midday*, and *sunset*.

These natural divisions of a day formed the groundwork of all diurnal arrangements among the early nations. The Jews reckoned their days from evening to evening; the time of sunset being considered the beginning of each day. But, as sunset (as we have just observed) occurs at different times in different periods of the year, the beginning of their day necessarily varied. The time of sunset in Judæa is about five o'clock at Midwinter, and about seven o'clock at Midsummer, which makes a difference of two hours in the point from which they commenced their day.

It was not until a subsequent period that *hours* were introduced among the Jews; for it would appear, from a passage in Nehemiah, chap. ix. v. 3, that the civil day was, about 450 B. C., divided into four parts. Again, David, in Psalm LV. v. 17, speaks of evening and morning and noon, as if they were stated points of division in the day.

Among the nations in which astronomy was first cultivated, was Chaldea, and it is natural to suppose that the first division of the day into *hours* was adopted *by that* people; for it would obviously be difficult to

compare the times of the appearances of the heavenly bodies with so large an unit of time as five or six hours. The first division was into twelve hours, but that was afterwards replaced by a division into twenty-four hours. They began their day at sunrise, and reckoned on twenty-four hours to the next sunrise: in fact, according to our mode of naming the hours, we should say that their day commenced an hour before sunrise, because the hour of sunrise was reckoned one. It is, probable, however, that, instead of employing the numbers to denote the divisions between these twenty-four periods, they applied them to the periods themselves, calling them "the first hour," "the second hour," and so on: in this sense, the notation would begin and end at the moment of sunrise.

The Egyptians computed their hours in a manner somewhat similar to our own; that is, they began the day at midnight; but here the similarity ends; for, instead of reckoning twice twelve hours, they went through the whole twenty-four, like the Chaldeans and Babylonians. The first mention of *hours* in the Bible occurs in Daniel iii. 6; and v. 5: in these cases, however, the word *time* or *moment* would convey the same meaning as the word *hour;* but, as the Jews obtained their notions of the division of the day into hours from the Chaldeans, when they were carried into captivity to Babylon, and as Daniel lived at that period, B.C. 570, it is probable that the sentences, just alluded to, really relate to *hours*.

The Jews, however, deviated from the plan adopted by their instructors, inasmuch as they began their day at sunset, instead of sunrise, and reckoned two series of twelve *hours each*, instead of one series of twenty-four

hours. These two series extended, one from sunset to sunrise, and the other from sunrise to sunset; and, as each period was divided into twelve equal parts, it necessarily followed that the night-hours were longer than the day-hours in Winter, and shorter in Summer, in consequence of the difference in the hour of sunrise: the word *hour*, therefore, had not the same definite meaning with them as it has now with us. The night was divided by the Jews, before their country became subject to the Romans, into *three* watches,—called in Latin "Vigiliæ,"—consisting of four night-hours each. These Vigiliæ were afterwards increased, under the Romans, to *four*, viz, *Even*, *Midnight*, *Cock-crowing*, and *Morning*.

In the earlier ages of Greece, it does not appear that hours were known; for Homer speaks of Morning, Evening, and Midday, in a manner analogous to that of David. Hippocrates is said to have brought the horary division of the day into practice in Greece, from having observed it in Egypt. There seems reason to believe that many of those nations which had no communication with the Chaldeans, reckoned the progress of time by *Nights;* for Tacitus speaks of that mode of computation, as having been in vogue among the ancient Germans. The same remark was made by Cæsar, with respect to the ancient Gauls; and it is known at the present day that some of the nations of central and southern Africa, the Mashoos, for example, reckon time by the lapse of nights. Indeed, our own household words, "se'nnight" and "fortnight," seem to be surviving proofs that a practice somewhat similar was once prevalent in Britain.

Confusion is sometimes created by applying the term

"day" both to the whole twenty-four hours, and to that portion of them during which the Sun is above the horizon; it has therefore been proposed to use the word "Nycthemeron" for the former,—thereby confining the term *day* to the latter. *Nycthemeron** implies *day and night* together.

The origin of the names of the days of the week is a curious sample of the influence which Astrology exerted over the minds of the "ruling powers" of those days. The seven primary planets (for *then* they were *all* called planets) Saturn, Jupiter, Mars, Sun, Venus, Mercury, and the Moon, were believed to take it in turn to preside over the affairs of the world, each one ruling for one hour, and then giving way to the next. The day was named after the planet who happened to be in the ascendant at the first hour of that day. Thus Saturn was said to be the ruling planet at the first hour of the Jewish sabbath; the sabbath was therefore named, after him, *Dies Saturni*, or the day of Saturn. The eighth, fifteenth, and twenty-second hours of that day, would likewise come under the dominion of Saturn; the twenty-third under Jupiter, the twenty-fourth under Mars, and the first hour of the following day under the Sun,—from which arose Sun-day, or *Dies Solis*. Proceeding in a similar manner, we find that the seven days, reckoning from Saturday, came in the following order:—Saturn's day, Sun's day, Moon's day, Mars' day, Mercury's day, Jupiter's day, and Venus' day; and from these titles the Latin names of the week were derived. The English names are well known to be derived from those of some old Saxon idols.

* A word compounded from the Greek, *νυξ, night*, and *ἡμερα, a day*.

In many uncivilized countries at the present day, the computation of time by *moons*, or months, is adopted. But this only relates to large portions of time; for smaller portions may obviously be more conveniently computed by the arrival of the Sun at the meridian, or the natural day.

The Jewish month was lunar, and calculated from the first appearance of the Moon, on which the "Feast of the New Moon" was celebrated. This was the beginning of the month. It was proclaimed by the sound of trumpets, and many additional sacrifices were offered:—hence the Psalmist says, "Blow up the trumpet in the new moon, in the time appointed, on our solemn feast-day." Psalm LXXXI. 3.

There is no particular reason why a division of the day into twenty-four hours should be preferred to any other: twenty or thirty-six, for instance, would be quite as well; but twenty-four having been chosen, other nations gradually adopted the same number, although they may vary in their modes of computing those hours. It was, however, obviously necessary to devise the means for measuring them equally. Varied, both in principle and in details, have been the means invented for this purpose. The sun-dial, the clepsydra or water-clock, the hour-glass, and wheel-clocks and watches, have been the chief contrivances; and all these have been and the latter still are employed by astronomers in estimating the motions of the celestial bodies. Tycho Brahé, of whom we have several times spoken, used a clepsydra in observing the diurnal courses of the stars.

I. The Sun-Dial.

We shall now proceed to show how the shadow of any object, on which the Sun is shining, may be made a measure of time. But, before doing so, we must shortly allude to a difference in the respective lengths of hours, as indicated by the Sun.

The Earth moves equably on her axis, but not equably in her orbit: that is, she moves through a twenty-fourth part, for instance, of her daily rotation in exactly the same portion of time every year, and in every part of the year; but, in moving through a given part of her annual orbit, she occupies a longer time at some periods of the year than at others. This irregularity in the Earth's motion proceeds from two sources: first, the Earth's motion round her axis not being parallel to her motion round the Sun; and second, the Earth's annual path round the Sun not being a circle, but an ellipse; as was shown in Chapter III. Both of these circumstances disturb the equability of the hours, as indicated by the Sun. The time, therefore, as indicated by the shadow of an opaque object, cast by the Sun, does not quite correspond with the time as indicated by a good clock or chronometer, the former being sometimes in advance, and sometimes in arrear, of the other. The deviation is, however, never more than $16\frac{1}{4}$ minutes, and can always be known by referring to the table of the "Equation of Time," in an Almanac.

Our readers may form a rough idea of the origin and nature of the Sun-dial by thrusting a stick upright in the ground, when the Sun is shining. By observing the shadow of the stick, as cast upon the ground, at

different hours and on different days, many useful facts may be elicited. 1st. The shadow will be shorter at noon than at any other part of the day. 2nd. It will be of the same length at any number of hours before noon as at the same hours after noon. 3rd. It will be longer at sunrise and at sunset than at any other part of the day. 4th. It will at any given hour on the 21st of March be just as long as at the same hour on the 21st of September; but at the same hour on any of the Summer days between those periods it will be shorter, and on any of the Winter days longer, than in March or September. 5th. The twelve o'clock shadow will, on every day in the year, be exactly north and south. The causes of these differences are to be found in the two-fold motion of the Earth; first, on her own axis, and secondly, round the Sun. The Sun is more elevated in Summer than in Winter; hence he casts smaller shadows in the former season. Again, he is more elevated at noon than in the forenoon or afternoon: hence again, the shadows are shorter at noon than at any other hour.

The shadow of the stick, therefore, would give us some knowledge of the hour of the day and of the season of the year, by comparing its length at different times. But we shall gain much more information if we attend to the *direction* of the shadow, as well as to its length. For instance, on the 21st of March and the 21st of September (the days of the vernal and autumnal equinoxes, when the lengths of the day and night are equal all over the world) the Sun rises exactly in the east, and sets exactly in the west. The shadow of the stick therefrom is cast due west at sunrise, and due east at sunset. In the Summer months the Sun

rises to the north of east, and consequently throws the shadow rather towards the south-west, while in Winter he rises southward of east, thereby throwing the shadow northward of west. Again, at twelve o'clock at noon, (in a northern latitude above the tropic of Cancer,) the Sun is always due south, and therefore casts a shadow due north.

Now, if all these facts were carefully noted, and marks made in the ground by which the direction and length of the shadow might be compared at different times, much information as to the progress of time and the seasons might be acquired; indeed a rude sort of Sun-dial would be constructed. All Sun-dials are merely contrivances, by which the shadow of the straight edge of a projecting piece of metal, or wood, becomes indicative of the number of hours that the Sun has been above the horizon, or, rather, the number of hours that he is distant from his meridian position. A stick, thrust upright in the ground, would even render information as to the season of the year in the following manner:—suppose an inhabitant of London (or of any other place in the same latitude, 51½°) fix a stick or rod upright in the ground, to the height of exactly two feet. Let him on the 1st of January note the shortest shadow thrown on that day, which will be at twelve o'clock at noon, as before stated. On measuring it he will find its length to be 7 feet 3¾ inches. Let him repeat the process on the 1st of each following month, and he will find that the shortest (or twelve o'clock) shadow will measure as follows:—

	Ft.	In.
1st of February	5	1
—— March	3	4
—— April	2	1¾

	Ft.	In.
1st of May	1	5¾
—— June	1	1½
—— July	1	1
—— August	1	4
—— September	1	10½
—— October	2	10
—— November	4	6
—— December	6	8½

At any time afterwards, therefore, he can, by measuring the noon-day shadow of a vertical rod two feet high, form a rough idea of the season of the year. We must not be understood to attribute any practical value to the foregoing mode of determining times and seasons; but only to observe, that on principles similar to these Sun-dials are constructed.

Our readers have probably seen a Sun-dial. It has been in some measure thrown into oblivion by those more convenient instruments, clocks and watches. The dial still remains, however, as an ornament on the open lawns of rural dwellings, where, fixed on a pedestal, it is exposed on all sides to the Sun. In some countries a Sun-dial is of more service than in others. In southern climates, where the atmosphere is purer and clearer than with us in the north, the dial is very necessary to adjust the clock by; the shadow projected by the style being more marked and constant than with us, owing to the more uninterrupted serenity of the heavens. An elaborate dial may be seen in Kensington Gardens, near the palace; and many old buildings, in and near the metropolis, contain these relics of the ingenuity of our forefathers.

Dials are chiefly *horizontal* and *vertical*. But, whatever be their position, there is always a project-

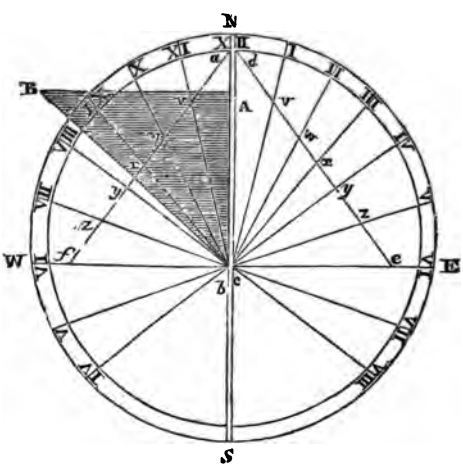
ing piece of metal or wood, the shadow of which, thrown on the dial, traverses a certain range of distance from one side of the dial to the other. The position of this index, or shadow-producing body, is a very important part of the construction of a dial; but, whatever be its shape, the edge which casts the shadow is called the *style;* the whole contrivance is termed the *gnomon;* and the part of the dial-plate on which the gnomon rests is the *sub-style.*

We will now briefly describe the construction of a horizontal and a vertical dial; these being the most practically useful, and therefore oftenest met with. It should be observed, however, that the style of every dial must coincide, or be parallel, with the axis of the Earth. It must, therefore, be elevated as many degrees above the dial-plane, as will accord with the latitude of the place. The equability of the shadow projected by the style, can only be preserved at all seasons and all hours by the parallelism of the style with the Earth's axis; because the apparent course of the Sun is thus at right angles with the style of the dial, as it is with the axis of the Earth; whence, it will easily be seen, results the *uniformity* of the shadow.

We construct a *horizontal* dial for the latitude of London, thus:—having described two concentric circles, within which the hour-numbers are marked, as in the annexed figure, we draw two diameters at right angles to each other, as N S and W E. The east and west line, W E, need not pass through the centre. If drawn lower down, as in the figure, it gives greater scope for the shadow of the gnomon during the middle of the day, when the dial is most available. We next divide each of the two upper quadrants into six parts,

which divisions, however, must not be equal, but the following order must be observed. From the twelve o'clock to the one o'clock line must be an angle of 11° 51′; from one to two o'clock = 12° 28′; from two to three = 13° 44′; from three to four = 15° 32′; from four to five = 17° 31′; and from five to six = 18° 54′: which together make up the quadrant of 90°. The same process must be repeated on the other side of the twelve o'clock line, and the dial will be properly

Fig. 53.



HORIZONTAL DIAL.

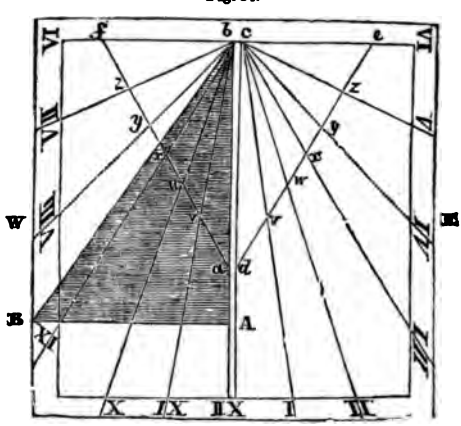
divided. The style must then be inserted where the six o'clock line crosses the meridian line, and it may be either a straight wire, or a thin piece of wood or metal formed into a right-angled triangle, as c A B, which is the gnomon. In our figure it appears to lie down, and

overlap some of the hour-lines beneath; but when used it must be turned up by a hinge at the side, *b* A, which is the sub-style. Thus, the gnomon is fixed upon the meridian or twelve o'clock line, N S, which is made double, in order to suit the thickness of the gnomon. When perfectly upright, one end of the sloping edge coincides with the point *b c*. This sloping edge, *b* B, thus becomes parallel to the Earth's axis; for, in adjusting the style, or constructing the gnomon, we made the style or line, *b* B, have an inclination equal to the latitude of the place = 51½° at London. When the dial is thus constructed, the shadow of the oblique edge of the gnomon, *b* B, coincides successively with all the hour-lines, from eight in the morning till four in the afternoon at Midwinter, and from four in the morning till eight in the evening at Midsummer: these being about the extreme hours of sunrise and sunset in the latitude of London. To mark these hours on the lower quadrants of the dial, the hour-lines twelve hours off are prolonged to the opposite part of the circle, as shown in the figure. The lines, *a f*, *d e*, are used when the angular distances of the hour-lines are taken from a scale. A horizontal dial for any other latitude must have the style arranged according to that latitude; and the hour-lines separated by angles which may be obtained from tables found in works on Dialling.

In a *vertical* dial the style is still parallel to the Earth's axis, but the noon hour-line is directed downwards. The style, in consequence, points downwards, and makes with the plane of the dial an angle equal to the complement of the latitude; that is, what the latitude wants of 90°. For London this is 38½°; which is the angle made by the style with the dial-plate.

The hour-angles are as follow:—from twelve to one, 9° 28′; from one to two, 10° 17′; from two to three, 12° 9′; from three to four, 15° 15′; from four to five, 19° 33′; and from five to six, 23° 18′. The cross-lines, *a f*, *d e*, are for taking these distances off from the scales of hours, latitudes, and chords. In other respects, the construction of this dial will be similar to that of a horizontal dial. A vertical dial needs only to have one-half of the hour-lines drawn, as the Sun never casts a shadow on it before six in the morning, or after six in the evening; its edges being directed east and west.

Fig. 54.

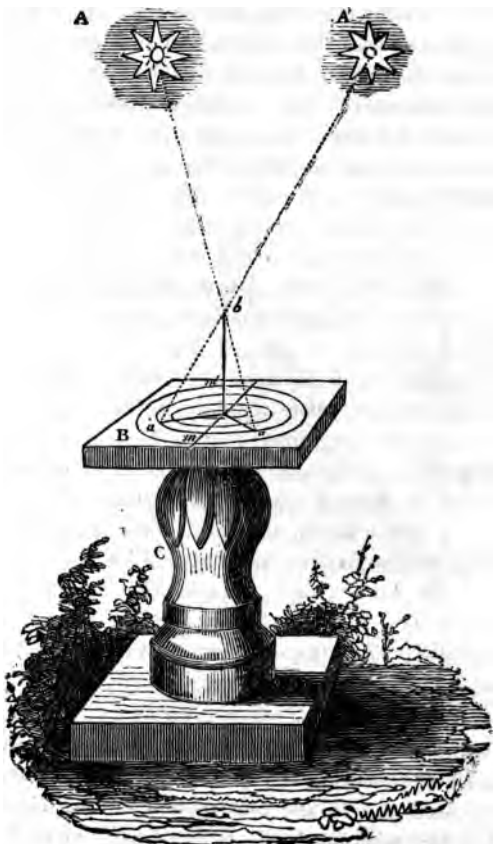


VERTICAL DIAL.

Before proceeding further, we must explain the method of procuring a meridian-line, which is especially necessary in the construction of the horizontal dial, before mentioned.

Suppose we were about to lay a dial-plate horizontally on the slab, B, of the pedestal, C, in the accompanying figure. We must, of course, make the double meridian-line coincide with the meridian-line, which

Fig. 55.



we shall obtain thus:—Having made the slab *level*, we draw several concentric circles, and fix a wire perpendicular at the centre. Suppose, for instance, that at ten o'clock the shadow of the wire touches the third circle from the centre at *a*, when the Sun is shining at A; at eleven o'clock the shadow touches the second circle; at half-past eleven o'clock, the innermost circle. We mark these places respectively where the shadow of the wire cuts each circle. At half-past twelve the Sun, having travelled round to A′, cuts the innermost circle; at one o'clock, the second circle; at two o'clock, the third circle at *a′*. We mark the circles as before. Then dividing these arcs of the circles equally, we draw the line from *m*, through the points of division to the centre; which line lies where the shadow from the wire, *b*, fell at twelve o'clock, solar time, and is continued to *m′*.

By the aid of an Almanac and a little calculation, a Sun-dial may be made to indicate the hour, by the shadow cast by the Moon, in this manner:—Observe what hour-line is marked by the shadow of the style: then find the Moon's age in an Almanac; take three-fourths of that number, and add the result to the hour indicated by the shadow, and that will be the real hour of the day. For example, suppose the Moon's age to be twelve days, and the shadow of the style to mark four o'clock in the afternoon: we take three-fourths of twelve, which is equal to nine, and add that to four o'clock in the afternoon, which gives one o'clock in the morning as the real time. The reason of this is, that if the Sun and Moon were on the same meridian at the same instant on any given day, the Moon on the following day would be about three quarters of an hour

later than the Sun in arriving at the same meridian: that deviation, therefore, has to be calculated, and added to the observed time. This method of finding time cannot, however, be altogether depended upon, on account of the Moon not always rising three quarters of an hour later than on the day before.

We observed that in climates not far removed from the Equator, the Sun-dial is more valuable than in regions nearer to the poles. We find accordingly that Babylon, or some neighbouring country, was the birth-place of the Sun-dial. Mention is made in the Bible, at the twentieth chapter of the Second Book of Kings, verse 11, of a Sun-dial as having existed in the time of Ahaz, which was about 730 years B.C. The passage is this,—"He brought the shadow ten degrees backward, by which it had gone down in the dial of Ahaz." The word used for *degrees* in the original Hebrew is equivalent to our term *steps*. Hence, St. Jerome expresses an opinion that there was a pillar, or column, erected near a flight of steps, leading up to the king's palace, and that the step, on which the shadow of the pillar happened to fall, indicated the position of the Sun at that moment.

II. The Quadrant.

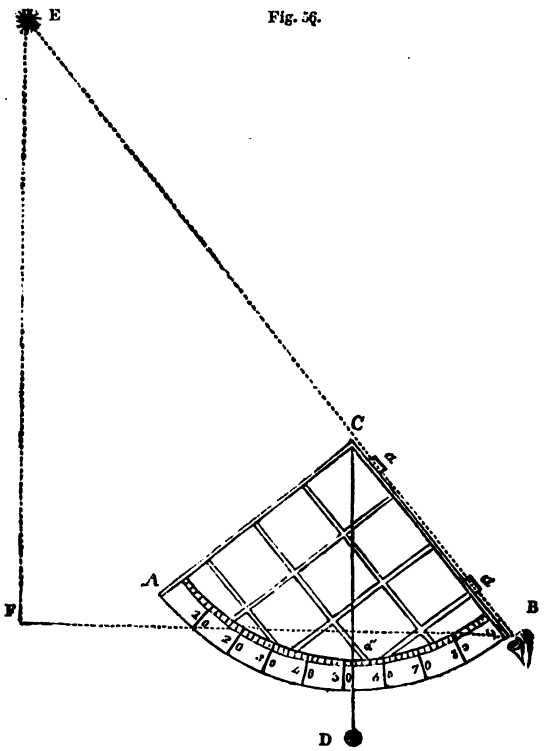
The Sun-dial is used on land; but the Quadrant or Sextant is chiefly used by the mariner, to enable him to determine his situation on the Earth's surface by reference to the real or apparent motions of the celestial bodies, whose angular motions he estimates by the use of this instrument. The origin of it was at about the termination of the middle ages, when mankind in the

West had awakened up to the cultivation of the arts and sciences, and the pursuit of geographical knowledge.

In the early part of the fifteenth century, John the First, king of Portugal, had effected some very important conquests over the Moors; in which he had been very materially assisted by his son, Prince Henry, who, being an able and active-minded cavalier, took delight rather in the more solid glories of learning and science, than in the fame of war, in which he had, however, of late highly distinguished himself. Upon the cessation of hostilities he retired to the promontory of St. Vincent, and lived at the sea-port town of Sagres, which he had himself founded, where he cultivated the science of Astronomy, for the purpose of making it available to the mariner, in guiding him over the ocean, when he had ceased from the servile tracking of the shore. He, in fact, established a naval college, and an observatory. He engaged to his assistance all the best-informed men of his time; and the point to which he especially directed his attention, was the practicability of sailing round Africa, and of thus reaching the East Indies. His ideas respecting the accomplishment of this project had been awakened, or enlarged, by intercourse with some well-informed persons at Ceuta, a town on the coast of Africa, opposite to Gibraltar, whither his father's military proceedings against the Moors had carried him. Prince Henry did not live to see the whole of his views accomplished; but the many minor discoveries which were effected under his auspices, laid up a fund of knowledge and experience for succeeding navigators to profit by. Maps were formed under his superintendence; by which means all the geographical knowledge respecting the Earth was

brought together; the different parts were marked out; and the rocks, coasts, and quicksands to be avoided, were all noted down. About this time also was first invented and brought into use the *Astrolabe**, the original of the Quadrant:—

Fig. 56.



THE ASTROLABE, OR QUADRANT.

* A word formed from the Greek, implying to *take* the height of the *stars*.

> That sage device, whose wondrous use proclaims
> Th' immortal honour of its authors' * names,
> The Sun's height measured.———

It was in principle an arch, to the extent of a quarter of a circle, such as A B; and the rim was divided into degrees and half-degrees. Its primeval use was to take the altitude of the North polar star, in order to determine the latitude of a place, which is its distance north or south from the Equator; for which purpose a plummet, C D, was suspended by a string from the centre of the instrument, C, and thus the angle of elevation of the heavenly body was marked. An eye at B, sees the star, E, through the sights, $a\,a'$; to make which observation the whole instrument must be so raised upwards, that the plumb-line, C D, shall fall vertically upon the quadrantal arc, A B. The arc included between A and a'' is the angular elevation of the star, E; or the angle E B F = 51°.

To a person situated at the Equator, the polar star will appear in the northern horizon. In proportion as he advances northward, this star will gain in altitude; so that, when he shall have arrived at the pole itself, the star will be vertical to him; the pole being 90° north of the Equator: hence the latitude of the place corresponds (nearly) with the altitude of the polar star. These observations would, of course, only serve for places in the northern hemisphere; as, on the southern side of the Equator, the polar star would be below the horizon. In the early stage of nautico-astronomical science, these considerations were sufficient for navigators; but now, to determine the latitude of a place accurately by an altitude of the polar star, corrections

* Two Jewish physicians, named Roderic and Joseph.

must be made for this star not being precisely vertical to the pole, but describing a small circle round it, owing to the diurnal revolution of the Earth.

The modern Quadrant is an improvement upon the ancient Astrolabe; and the Sextant is an improvement upon the Quadrant. Moreover, the Reflecting Circle is an improvement upon the Sextant.

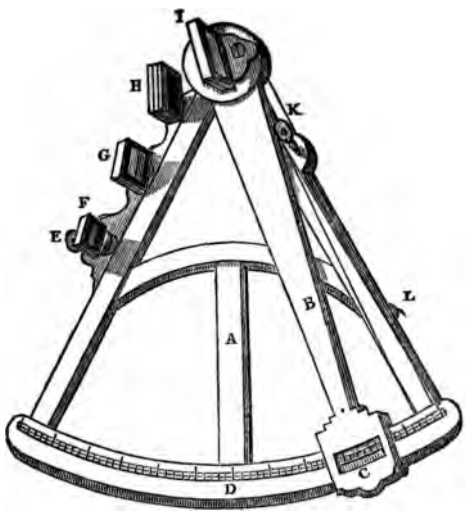
The Quadrant is more properly termed an *Octant*, because its arc embraces the *eighth* part of a circle, though we are thereby enabled to measure a quadrantal arc, or the fourth of a circle, = 90°. The *Sextant*, however, has an arc to the extent of one *sixth* of a circle; but we are enabled by its means to measure an arc of 120°, or the third part of a circle. The Reflecting Circle, a still more accurate instrument than the foregoing, has an entire circle graduated, and enables us to measure larger arcs than we could do with the beforementioned instruments.

The principle of these three comparatively modern instruments being the same, we proceed to illustrate their nature and use, by reference to the following figure of the QUADRANT. This instrument was invented, or adapted for use, by John Hadley, who, in the year 1731, first communicated its principles to the Royal Society, which were soon after published in the *Philosophical Transactions*.

A is the frame-work of the Quadrant, and affords convenience for grasping it during observations on board. B is the index, which turns on the centre of the circle, of which the divided limb, D, is a part or arc. The index, B, carries the index-glass, I, perpendicular to the plane of the index, and in a line with 0 on the vernier scale, C. G is the fore horizon-glass half silvered,

and so placed by means of its adjustment as to be parallel to the index-glass, when 0 on the vernier is at 0 on the limb D. K is a sight hole, through which the horizon is seen through the unsilvered part of the glass at G. At H is a set of coloured glasses, by using one or more of which we may protect the eye from the direct rays of the Sun. E F is the back horizon-glass and sight. This glass is silvered at both ends, and in the middle there is a transparent slit, though which the horizon may be seen. At L is a nick to prevent the index from slipping off from the frame.

Fig. 57.



HADLEY'S QUADRANT.

Now the Sextant is an instrument rather more finished and nice in its construction than the foregoing: being

more delicately graduated, and having telescopes for more perfect and distinct vision. The limb, D, of the Quadrant is divided into 90 equal parts or degrees, which degrees are subdivided by means of the vernier, C, into minutes, 60 of which = 1 degree. But we more usually find that each of the degrees on the arc, D, is divided into thirds, each = 20′; each of which thirds is subdivided by the vernier into twentieths, or single minutes.

In consequence of certain optical principles in the reflection of light, the arc, D, though only the eighth part of a circle, affords us an estimate of angles to the extent of 90°. We proceed, therefore, to show the *use* of this instrument.

When "a sight," as it is commonly termed, is taken, or when an observation is to be made,—of the Sun, for instance,—the index, B, is moved along till the lower limb of the Sun is seen through the sight-hole, K, in the silvered part of the horizon-glass, G, and in the same line with the natural horizon seen through the unsilvered part. Then the portion of the arc, D, over which the index has been moved, is the measure of the angle. This method of observing the altitude of a celestial body is termed the *fore observation*. The other method is when the observer's back is towards the object, and it is brought over to the opposite part of the horizon; the observer then looks through E; and this mode of observing is termed a *back observation*. This latter method of observing is, however, very seldom used; and is requisite only when the horizon under the object is broken by adjacent shores, or rendered indistinct by fogs, or any other impediments.

The principal use of the Quadrant is then to make

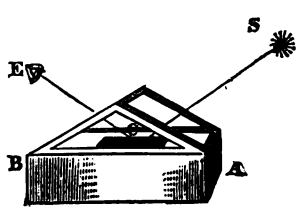
observations on board ship,—to find the altitude of the Sun or of a star; that is, the angle which the elevation of such heavenly body makes with a horizontal line, or the boundary line of the sea, as seen in the distance. This angle can never be more than 90°, or the distance from the zenith to the horizon; and the altitude of the Sun reaches this extent only at mid-day, and in certain latitudes. The Quadrant, therefore, whether with relation to the Sun or a star, is always sufficient for taking the latitude; but, as a larger arc is often necessary to be measured in finding the longitude by lunar distances, the mariner usually has recourse to the Sextant.

In the absence of the Sun-dial, the Quadrant or Sextant is useful on land for the regulation of time by equal altitudes of the Sun. If we wish to regulate a watch or clock by this mode, we observe by the time-piece at a certain moment before noon, say one hour, the precise altitude of the Sun. We then wait till the Sun has passed the meridian, and endeavour to notice the precise moment when the altitude of the Sun is the same as we took it before noon. It is clear that, as the Sun continually rises in the heaven till mid-day and then begins to sink, the arc comprised between the two altitudes must be equally divided by the meridian of the place on which the Sun is at twelve o'clock. If the times of the semi-arcs be equal, the time-piece is right by the Sun. If, however, the times of the semi-arcs be unequal, the clock or watch must be adjusted thus:—At eleven o'clock, we suppose that we observed the Sun to have a certain altitude, by our time-piece, which we wish to correct. At twenty minutes past one, we observe the Sun to have precisely the same altitude. The time from eleven o'clock till twenty minutes past one

being divided, gives us ten minutes past twelve, by our time-piece, as the moment of the Sun's crossing the meridian; thereby showing that our time-keeper was ten minutes too fast by the Sun. If we rectify according to this amount, and allow for the equation of time, we have obtained the true clock time for the place of observation.

It is, however, necessary to observe that, in using the Quadrant, Sextant, or Reflecting Circle by land, to take the altitude of celestial objects, the visible horizon, owing to its irregularity, is of no use to us. We therefore use an *artificial* horizon, which consists of a surface of quicksilver in a wooden trough, with a smooth piece of glass laid on the top of it. The whole is covered with two panes of flat glass placed in the form of a roof, to prevent the quicksilver being agitated by the wind.

Fig. 58.



ARTIFICIAL HORIZON.

A B is the box and roof: C is the pane of glass within, floating on the mercury, which of course lies horizontally. A ray of light coming from the Sun at S, falls on the glass at C, and is reflected at an equal angle to the eye at E. The angle is found by making the image in the

horizon-glass of the instrument coincide with the image reflected from C, and seen through the unsilvered part of the same glass. The arc passed over by making these two images coincide, is thus *double* of the real angle; for which reason, the quadrant will not measure by itself an angular quantity of more than 45°.

Thus far have we explained the nature and uses of such primitive astronomical instruments, as are concerned in the investigations of time, and as may be conveniently used by the general reader of Astronomy. More searching and finished practical means for pursuing the study of astronomical science, are seldom to be met with beyond the walls of an observatory.

The following *Glossary* is intended to assist the reader, both in the comprehension of the astronomical terms and allusions used in the present volume, and in his proceeding to the study of more elaborate works on the subject of the heavens.

GLOSSARY.

BERRATION OF LIGHT. (Latin, from *ab*, from, *erro*, to wander.) The deviation of the direction in which a spectator sees a planet, star, &c., from the *true* one, as expressed by a straight line, supposed to be drawn from his eye to the object. This deviation is caused by the change of place in space of the Earth, and therefore of the spectator, effected during the time taken by light to travel from the object to him. In consequence of this motion, the axis of the telescope through which we see any body as distant as the planets and stars, at any moment, is not coincident with the line that would really pass through the object at that moment.

.CCELERATION, of the Moon's mean Motion. A secular variation in that mean motion, occasioned by one in the eccentricity of the Earth's orbit. The Moon is *quickened* in her motion round the Earth, in consequence of the diminution of the eccentricity of the Earth's orbit, causing her motions to be less influenced by solar attraction. This *acceleration* will go on, for countless ages to come, till the eccentricity has reached a minimum; when it begins again to increase, the *acceleration* will become a *retardation*.

\CCELERATION, of Nebulous Comets, which produces a diminution in their periodic revolution, is occasioned by the resistance experienced by such highly attenuated bodies, in moving through an ethereal medium, which appears to fill space.

ACHRONICAL Rising or Setting of a Planet or Star, is when it rises at sun-set, or sets at sun-rise.

ÆRA. A certain period of time, from which chronologists and astronomers begin their computations.

ALGOL. The (Arabic) name given to the fixed star, β Persei. It is a variable star, remaining of the brightness designated the second magnitude for about two days, and then suddenly diminishing to the fourth magnitude, and regaining its splendour in about seven hours; the period of this alternation is $2^d\ 20^h\ 48'$.

ALMACANTERS. Certain imaginary circles which, in every position of the globe, are supposed to be drawn parallel to the horizon. They are parallels of altitude.

ALTITUDE. (Latin, *height.*) The arc of an azimuth circle passing through a star, planet, &c., intercepted between the star and the horizon.

ALTITUDE, MERIDIONAL. The altitude of a star, &c., when on the meridian.

AMPHISCII. (Greek, from *αμφις*, on both sides, and *σκια*, a shadow.) The inhabitants of the torrid zone; so called, because their shadows fall at one time of the year towards the north, and at another southward.

AMPLITUDE. (Latin, *extensiveness.*) The arc of the horizon comprised between the east or west points, and that at which a planet, star, &c., either rises or sets.

ANGLE OF POSITION OF A STAR, is an angle formed by two great circles intersecting each other in the place of the star, the one passing through the pole of the equinoctial, the other through the pole of the ecliptic.

ANOMALY. (Greek, from *a*, without, *ὁμαλος*, equal.) The angular deviation from the *mean* place of a planet, &c., as conceived to move in a circular orbit; in consequence of its real *unequal* motion in an elliptic orbit.

ANOMALY, MEAN. The angular distance between the perihelion and the *mean* place of a planet at any period of its revolution.

ANOMALY, TRUE. The angular distance between the perihelion and the *true* place of a planet, &c., at any period of its revolution.

ANOMALY, ECCENTRIC. The angle at the centre of the imagi-

nary circular orbit of a planet, &c., described on the major axis of its elliptic orbit, formed by radii drawn to the point of the perihelion and to the *mean* place of the planet.

ANTECEDENTIA. (Latin, *a going before.*) A motion of the heavenly bodies contrary to the order of the signs.

ANTIPODES. (Greek, *αντι*, opposite to, and *ποδες*, feet.) Those who are exactly on the opposite side of the Earth.

ANTŒCI. (Greek, from *αντι*, opposite to, and *οικεω*, to dwell.) Those who live on the same meridian, and at the same degree of latitude, but on the opposite side of the equator.

APHELION. (Greek, *απο*, distant from, *ἡλιος*, the Sun.) The point of a comet's or planet's orbit at which it is farthest from the Sun; it is the vertex of the major axis of the mean elliptic orbit.

APOGEE. (Greek, *απο*, distant from, *γη*, the Earth.) The point of the Moon's or a planet's orbit at which it is most distant from the Earth.

APSIDES. The two points in the orbit of a planet, in which it is at its greatest and least distance from the Sun. The line joining those points is called *the line of the apsides.*

ARC. (Latin, *arcus*, a bow.) The measure of angular distance. A *diurnal* arc is that described by the Sun, or other heavenly body, from rising to setting. The *nocturnal* arc is from setting to rising.

ARCTURUS. The name for *α* Bootis. It has a proper motion, causing an annual average decrease in right ascension of 1·2″, and in declination of 2″.

ARIES. (Latin, *a ram.*) A constellation near the ecliptic; one of the intersections of the planes of the ecliptic and equator was situated in this sign about 2230 years ago: hence, ever since, this intersection has been called the first point of Aries, as being that from which the division of the ecliptic into signs commences. The character for this constellation is ♈.

ASCENSION, RIGHT. (Latin, from *ascendo*, to climb, to mount.) The distance of the point, in which a *meridian* passing through the centre of a star or planet cuts the equator, measured on the equator in degrees from the first point of Aries.

ASCENSION, OBLIQUE. The arc of the ecliptic intercepted from the first point of Aries, by a *meridian* passing through the centre of the star or planet.

ASCENSIONAL DIFFERENCE. An arc of the equinoctial, contained between that point of it, which rises with the Sun, Moon, or star, and that which comes to the meridian with them; or it is the time the Sun rises or sets, before or after six o'clock.

ASCII. (Greek, *α*, without, and *σκια*, a shadow.) Those people who have the Sun in their zenith at midday, and so have no shadow.

ASPECTS. Certain positions of the planets, as referred to the ecliptic.

ASTRONOMY. (Greek, from *αστρον*, a star, *νομος*, a law.) The science which treats of the motions of the Earth and heavenly bodies, and of the laws governing those motions; it is divided into

ASTRONOMY, PHYSICAL, which investigates the laws of the motions of the Earth and other planets, their satellites, &c., and the oscillations of the fluids at their surfaces: it is a branch of *mixed* mathematics.

ASTRONOMY, PRACTICAL, which treats of the use of instruments in observing the positions, &c., of the heavenly bodies, and of the means for calculating their future relative positions from the data furnished by observations.

ATMOSPHERE. (Greek, *ατμος*, vapour, and *σφαιρα*, a globe.) The air which surrounds the Earth.

ATTRACTION. (Latin, *a drawing towards.*) A property of matter, by which bodies approach each other, without any sensible agent drawing or impelling them.

AXIS. (Latin, an *axle-tree.*) The diameter on which a planet, &c., revolves.

AZIMUTH OF A STAR, &c. The arc of the horizon intercepted between the meridian and the great circle passing through the star and the zenith.

AZIMUTH CIRCLES. All great circles passing through the zenith and nadir of any place on the Earth's surface.

BINARY STARS. Some of the fixed stars when examined by a powerful telescope are found to be attended by a second, which either revolves about the first, or else both appear to revolve about a common centre of gravity. The most remarkable binary stars are, γ Virginis, η and γ Coronæ, Castor, ξ Bootes, τ and λ Ophiuchi, ϵ Arietis, Atlas Pleiadum, η and ζ Herculis, γ Leonis, and ξ Ursæ Majoris.

BISSEXTILE. (Latin, *double-sixth.*) Leap-year was so called by the Romans, because they reckoned the sixth day of the calends of March twice over.

CARDINAL POINTS. (Cardinal, from the Latin *cardo*, a hinge.) On the horizon, they are the four chief points of the compass, on which the others depend: east, west, north, and south. The cardinal points of the ecliptic are the first points of the signs Aries, Cancer, Libra, and Capricorn. The cardinal points of the heavens are the zenith, the nadir, and the points where the Sun rises and sets.

CENTRIFUGAL FORCE. That which a body, constrained by gravitation, or other power, to revolve in a curve, continually makes to fly off in a right line, a tangent to that curve. It is the antagonist force to gravitation, through which, a body revolving in an orbit, is prevented from falling to the larger one which attracts it.

CENTRIPETAL FORCE. That force by which any revolving body tends towards the centre of its orbit. Centrifugal is *centre-flying;* centripetal, *centre-seeking:* both from the Latin.

CIRCUMPOLAR STARS. Such as revolve about the Pole-Star.

CLIMATE. (Greek, *an inclination of the heaven.*) A part of the Earth contained between two small circles parallel to the equator; and of such a breadth, that the longest day in the parallel nearer to the pole, exceeds the longest day in the parallel of latitude nearer the equator, by half an hour, in the torrid and temperate zones; or by a month in the frigid zones:—so that there are twenty-four climates between the equator and each polar circle, and six climates between each polar circle and its pole.

Hence, it appears, that all places situated on the same parallel of latitude have the same climate, astronomically speaking; but we must not infer from thence, that they have the same atmospheric temperature. For this reason, and because the division of the Earth's surface into climates is only arbitrary, and founded upon no precise rule; such a division is not now much used in Astronomy, but belongs rather to the department of Physical Geography.

COLLIMATION, LINE OF, (Latin, *an aiming at,*) is an imaginary line joining the centres of the eye-glass and object-glass of a telescope.

COLURES. Two great circles, or meridians, one of which passes through the solstitial points, Cancer and Capricorn, and the other through the equinoctial points, Aries and Libra.

COMET. (Greek, from κομη, hair.) Bodies, or masses of vapour, moving through space, either in parabolic or extremely eccentric elliptic orbits, having the Sun in the focus: in the case of an elliptic orbit, the comet revolves periodically about the Sun like a planet; as it is probable most of those do which have appeared to belong to our solar system.

COMPRESSION. (Latin, *pressing together.*) The difference between the polar and equatorial diameters of an ellipsoid or spheroid of revolution.

CONJUNCTION, is when two stars, seen from the Sun or the Earth, appear in the same point of the heavens, or answer to the same degree of the ecliptic.

CONSEQUENTIA. (Latin, *following with.*) A motion of the planets, according to the order of the signs.

CONSTELLATION. (Latin, *stars clustered.*) A group of the fixed stars, to which the name of an animal, or other object, has been given, either merely for distinction's sake, or from some fancied resemblance.

COSMICAL Rising or Setting of a Planet or Star, is when it rises with the Sun in the morning, or sets with him in the evening. The terms *cosmical, achronical,* and *heliacal,* were used by the old poets in reference to the rising and setting of the Sun; but the derivation of the two former, with regard to their accepted meaning, is by no means clear and satisfactory.

CULMINATION. (Latin, *ridge of the roof of a house.*) The act of coming to the meridian, in the case of any star or planet, is so called, because it then attains its greatest altitude.

CURTATE DISTANCE. (Latin, *foreshortened.*) The length of the line drawn from the centre of the Sun to the point in which a perpendicular to the plane of the ecliptic meets that plane when drawn from the centre of the planet. The curtate distance of a planet is the co-ordinate projection of the radius vector on the plane of the ecliptic.

CUSPS. (Latin, *points.*) The horns of the crescent Moon are thus designated in astronomical language.

CYCLE. (Greek, κυκλος, a circle.) A series of changes, which, being completed, the cycle begins again.

DAY. The portion of time occupied by one revolution of a planet, &c., on its axis. With regard to the Earth, this interval is ascertained by the successive return of any meridian to any heavenly body; the day is accordingly either *solar* or *sidereal.*

DAY, APPARENT SOLAR. The time which elapses between the return of the Sun's centre to the same meridian, and varies from day to day during the year, owing to the unequal motion of the Earth in its orbit, and to the obliquity of the ecliptic.

DAY, MEAN SOLAR. The time which would elapse between the consecutive returns to the same meridian of an imaginary *mean* sun, supposed to move in the plane of the Equator with a constant motion, being the *mean* of the real Sun's motion in right ascension: it is, therefore, the *mean* of all the real days and fractions of a day which make up the tropical year.

DAY, MEAN SIDEREAL. The time which elapses between the consecutive returns of any, the same, fixed star to the same meridian. It is immutable and unvarying, because the revolution of the Earth on its axis is proved to be, and ever to have been, performed in precisely the same interval of time; and the star being at an infinite distance, when compared to the diameter of the Earth's orbit, the diurnal revolution of the Earth referred to that star is precisely the same as if the Earth stood still in space, and only turned on its axis.

DAY, ASTRONOMICAL, is reckoned from noon to noon, and consists of twenty-four hours. This is a natural or *full* day; being of the same length in all latitudes. The NAUTICAL day used at sea is similar; but this latter begins twelve hours before the Civil day, and the former twelve hours after: the CIVIL day begins at midnight, and is likewise a *full* day.

DAY, ARTIFICIAL, is the time elapsed between the Sun's rising and setting, and varies with the latitude of the place.

DECLINATION. (Latin, from *declino*, to decline, to deviate.) The arc of a meridian intercepted from the equator by the centre of a planet, or star, &c.

DICHOTOMIZED. (Greek, *bisected*, or *divided in two*.) A term applied to the half-moon.

DIGIT. The twelfth part of the Sun's and the Moon's apparent diameter.

DIRECT. A planet is said to have a direct motion, when it moves according to the order of the signs.

DISK. (Latin, *discus*, a quoit.) The round face of the Sun, and of the Moon, appearing flat, owing to their great distance.

DOMINICAL LETTER. One of the first seven letters of the Alphabet, usually marked in red, and used in Almanacs for distinguishing the *Sundays* thoughout the year.

EARTH, considered astronomically, is one of the planets revolving round the Sun, which, with it and the comets pertaining, constitute the Solar system.

ECCENTRICITY, of an Ellipse, is the distance of either focus from the centre. (Greek, εκ, from, κεντρον, a centre.)

ECLIPSE. (Greek, *a failure.*) When a planet, or satellite, is partially or totally hid from our view, by the interposition of another planet or satellite, the former is said to be *eclipsed* by the latter: an eclipse also happens when a satellite passes through the shadow of its primary; but it is usual to apply the term only to the obscuration of the Moon, by the shadow of the Earth, and to the obscuration of the Sun by the body of the Moon; while the passage of the Moon over any of the stars or planets is commonly termed an *occultation.* When Mercury or Venus is seen to pass across the disk of the Sun, the phenomenon is termed a *transit.*

ECLIPTIC. The plane of the Earth's mean orbit, considered as a standard, to which the orbits of the other planets and satellites are referred.

ELEMENTS. Certain quantities relating to the motion of a heavenly body, deduced from observations and from the general laws of gravity, by which its mean orbit in space may be precisely determined; and, by means of calculations made from these statements, its position in

that orbit may be ascertained at any instant, past or future. There are seven of these elements pertaining to a body moving in an elliptic orbit. 1. The greater axis. 2. The eccentricity. 3. The longitude of the perihelion. 4. The longitude of the ascending node. 5. The inclination of the orbit to the plane of the ecliptic. 6. The longitude of the epoch. 7. The periodic time of the body's revolution in the orbit.

ELEVATION OF THE POLE, (from the Latin, *lifting up,*) is an arc of the meridian, contained between the pole and the horizon, which is always equal to the latitude of the place, or the distance of the zenith from the equator.

ELLIPSE, (from the Greek, ελλειπω, to pass over, leave out.) The section of a cone by a plane, not parallel to that of the circular base of the solid, which plane cuts both sides of it. The mean orbits of all the planets and satellites are ellipses, the Sun or the primary occupying one of the foci.

ELLIPTIC. An adjective formed from the preceding word, and applied to the orbits of the planets, &c., to distinguish them from those of comets and asteroids, which are *apparently* parabolic.

ELONGATION. (Latin, *distance off.*) The angular distance of a planet from the Sun.

EMERSION. (Latin, *an issuing out.*) The time when a secondary planet, that has been eclipsed, begins to recover its light.

EPACT. (Greek, *to be added.*) The number of days *to be added* to the Lunar year to make it equal to the Solar year.

EPICYCLOIDS. (Greek, επι, upon, κυκλος, a circle.) These are formed by one circle rolling upon the circumference of another, instead of in a straight line.

EPOCH. (Greek, εποχη, retention, delay.) A point of time signalized by some remarkable event, from which time

other subsequent events are dated. Hence, in astronomy, if the position of a heavenly body at any period be determined, by observation of its relative position to others at that time, that time becomes an *epoch* for that body, and the longitude of it then is one of the elements, by means of which its position at any other times may be calculated.

EQUATION. In astronomical language certain quantities are so termed, which are to be added or subtracted from the *mean* data, to obtain the true data for calculating any phenomenon. See following.

EQUATION OF CENTRE. The angle formed by two radii vectores drawn from the centre of the Sun; one to that of the planet in its *true* place, and the other to the point where the planet would have been, if it had moved equably in a circular orbit, of a radius equal to its mean distance, and having the major axis of the elliptic orbit for its diameter.

EQUATION OF TIME. The difference between that indicated by the Sun, called *apparent* time, and that given by a clock adjusted by an imaginary Sun supposed to move in the equator with a constant equable mean motion. (See Time.)

EQUATION, ANNUAL. A lunar perturbation in longitude caused by the variation in the distance of the Earth from the Sun, owing to the eccentricity of the Earth's orbit. When the Earth is in its perihelion, the increased attraction of the Sun dilates the lunar orbit, and, consequently, diminishes the Moon's angular motion; but the reverse takes place when the Earth is at the aphelion. This change in the Moon's angular motion is the annual equation.

EQUATOR. (Latin, from *æquus*, equal.) The great circle of a sphere; the plane of which is at right angles to the axis of rotation. The *terrestrial* equator is the imaginary line on the Earth's surface, which is everywhere

equally distant from both poles. All places on this line have the day and night equal all the year round. The *celestial* equator is the circle of the imaginary sphere, which is everywhere ninety degrees distant from the two poles: it is, in fact, the terrestrial equator carried out to the starry heavens.

EQUINOX. (Latin, *equal night.*) The Earth is said to be in the equinox when she is in those points of her orbit, at which the radius vector lies in the plane of the equator. This occurs twice a year, and at these times the day and night are of equal length all over the Earth.

EQUINOX, AUTUMNAL; that in which the Earth is when the Sun, having no declination, is about to attain South.

EQUINOX, VERNAL; that in which the Earth is, when the Sun has no declination and is about to attain North declination.

EQUINOXES, LINE OF. The line joining the two points in the Earth's orbit, where she is when the Sun's centre is in the plane of the equator.

ETHER. A fine subtle fluid, which is supposed to fill the whole celestial space between the heavenly bodies and our atmosphere.

EVECTION. (Latin, *carrying out.*) A perturbation of the Moon in the line of her radius vector, being the result of one portion of the Sun's attraction, when that attraction is decomposed in the direction of that line, and in another tangential to the Moon's orbit. The evection tends to diminish or increase the eccentricity of the lunar orbit, but its effects depend on the position of the line of the apsides, and on the Moon's distance from the perigee.

FACULÆ. (Latin, *little torches.*) These are bright spots seen on the face of the Sun, or other heavenly body.

FOCUS. (Latin, *a fire-place*, or *source of heat.*) One of the two points from which an ellipse is generated. The

Sun is in one of the foci of the Earth's orbit, and is its source of light and heat.

GALAXY. (Greek, *milky.*) A name given to the large nebulous zone in the heavens, commonly called the *milky way.*

GEOCENTRIC. (Greek, *central, Earth.*) The latitude and longitude of a planet, &c., are so called, as determined from the Earth, and not when referred to the Sun as the centre of the celestial sphere.

GIBBOUS. (Hebrew, *convex.*) That phase of the Moon, which is greater than half, and less than full.

GOLDEN NUMBER. The ordinal number of any year in the lunar cycle.

GRAVITATION. (Latin, *weightiness.*) That power, in obedience to which every material atom attracts, and is attracted by, every other with a force varying inversely as the squares of the distances at which they are apart. The sensible *weight* of all terrestrial bodies is the result of the attraction of gravitation of them by the Earth.

GRAVITATION, LAWS OF. 1st. It is *directly* proportional to the mass. 2nd. It varies *inversely* as the squares of the distances.

GREAT CIRCLE, of a Sphere, is that formed by the intersection of the spherical surface with any plane that passes through the centre of the solid. The principal great circles referred to in Astronomy are the Equator, the Ecliptic, the Meridians, and the Azimuth circles.

GYRATION, CENTRE, OR SURFACE OF, (Latin, *turning,*) is that point or surface in a body that rotates on an axis, into which, if the whole mass could be concentrated, the angular velocity of rotation produced by a given force would remain the same. In a solid sphere, the radius of the *sphere of gyration* is equal to the square root of two-fifths of the radius of the sphere.

HELIACAL. (Greek, *relating to the Sun.*) The *rising* of a

star or planet is said to be heliacal, when it appears a little before that of the Sun: and when the star or planet, at its *setting*, is so hid in the Sun's beams as not to be seen above the horizon after him in the evening, it is said to set heliacally.

HELIOCENTRIC. (Greek, *central*, *Sun*.) The latitude and longitude of a planet are called heliocentric, when they are supposed to be referred to the centre of the Sun, and not as seen from the Earth.

HETEROSCII. (Greek, ετερος, one way or other, σκια, a shadow.) A name given to the inhabitants of the temperate zones, because their shadows at noon always fall one way, north or south.

HORIZON. (Greek, οριζω, to bound.) The *sensible* horizon is the circular boundary of sight; the *rational* horizon is an imaginary plane, passing through the centre of the Earth, parallel to the sensible horizon. The latter determines the rising and setting of the heavenly bodies.

HOUR-CIRCLES. Meridians.

HYPERBOLA. (Greek, from υπερβαλλω, to exceed, pass over.) A section of a cone, the plane cutting the opposite conical surfaces; hence, the curve is formed of two unconnected branches, each indefinitely extended in opposite directions, and each branch having a focus situated within its concavity and lying in the principal or transverse axis. No heavenly body that we know of has the hyperbola for a mean orbit.

IMMERSION. (Latin, *a dipping into*.) The moment when a satellite enters into the shadow of its primary.

INCLINATION OF AN ORBIT. The angle, formed by the plane of the orbit of a heavenly body, with the ecliptic.

INEQUALITIES. The *quantities* by which the real positions of the heavenly bodies are made to deviate from their *mean* places, in consequence of the disturbances produced in their motions by their mutual attraction; these inequalities are of two kinds.

INEQUALITIES, PERIODIC; those produced in the mean motions of the planets and satellites, from their relative positions in their respective orbits. They are so called, because they pass from the minimum to the maximum of their effects, and back again, in comparatively short periods of a few months, years, or centuries.

INEQUALITIES, SECULAR; those produced in the mean motions of the planets, &c., by the relative position of their orbits, whose forms and situations are altered in consequence, by exceedingly minute quantities in immense periods *(sæcula)* of time.

INFERIOR PLANETS are those, whose orbits are between the Sun and the orbit of the Earth: they are also called *interior*.

INGRESS. (Latin, *entrance*.) This term is usually employed to denote the Sun's entrance into any of the signs of the Zodiac.

INVARIABLE PLANE, of a system of bodies in motion, such as those constituting the solar system, is stationary in infinite space, if the common centre of gravity of the system is so; but if this centre of gravity move in space, the invariable plane always moves parallel to itself. The invariable plane is such, that the sum of the products of each mass multiplied into the projection on this plane of the areas, described in a given time by the radius vector of each mass respectively, will be a *maximum*.

LATITUDE, (from the Latin, *width*.) The terrestrial latitude of any spot on the Earth's surface, is the arc of the meridian of that spot, included between it and the equator: it is termed north or south, according as the place lies on one or the other side of the equator.

LATITUDE, CELESTIAL. The latitude of any heavenly body is that arc of a great circle passing through the body and the poles of the ecliptic, which is intercepted between the body and the ecliptic.

LATITUDE, HELIOCENTRIC. That of any planet as determined with reference to the Sun's centre, and not as seen from the Earth.

LATITUDE, GEOCENTRIC. That of a planet as seen from the Earth.

LESSER CIRCLES, are those whose planes do not pass through the centre of the Earth.

LIBRATION. (Latin, *balancing.*) The difference in the quantity of the Moon's surface that becomes visible according as it is viewed from different points of that of the Earth, is termed the libration of the Moon; also the oscillation that takes place of the greater equatorial diameter of a satellite about its radius vector, that greater diameter being always directed towards the primary, in consequence of the attraction that draws the equator of the satellite out of its circular figure.

LONGITUDE. (From the Latin, *length.*) The terrestrial longitude of any spot on the Earth's surface, is the arc of the equator intercepted between the meridian of that spot and the prime meridian from which the longitude is reckoned.

LONGITUDE, CELESTIAL, of any planet, &c., is the arc of the ecliptic measured from the vernal equinox to the point where a great circle, passing through the planet and perpendicular to the plane of the ecliptic, cuts the ecliptic.

LONGITUDE, HELIOCENTRIC. The longitude of a planet, &c., as it would be determined if seen from the Sun's centre.

LONGITUDE, GEOCENTRIC. That of a planet as seen from the Earth.

LUNATION. (Latin, *Luna*, the Moon.) The time which it takes the Moon to go through all her phases, or the time from New Moon to New Moon again; being the synodical month of about 29½ days.

MACULÆ, (Latin, *dark spots,*) which appear on the face of the Sun, or other heavenly body.

MAGNITUDES. The different apparent sizes of the fixed stars.

MEAN; a number or magnitude intermediate to two others: it is of two kinds. The *arithmetical* mean is equal to half the *sum* of the given magnitudes or numbers; the *geometrical* mean is equal to the square root of the *product* of the two numbers or magnitudes. The mean of more numbers or magnitudes than two is found, by dividing their *sum* by the number of them.

MEAN DISTANCE, of a Planet, or Satellite, is half the major axis of its orbit, conceived as a conic section.

MEAN RADIUS, of a Spheroid, as the Earth may be considered to be, is the mean between its greatest and least, or between its equatorial and polar, radii.

MEAN TIME. See Time.

MERIDIAN, (Latin, *meridies, quasi, medius-dies,* mid-day or noon;) *generally,* all great circles, produced on the imaginary surface of the celestial sphere, by planes passing through the axis of rotation of a planet. The *meridian* of any specific place on the Earth's surface is such a circle, or the plane producing it passing through that place. Also the line supposed to be drawn on the Earth's surface, through all those spots on it which have the Sun on their meridian, at the same instant of time.

MONTH. This word is derived from *Moon.* The *periodical* Month is the time in which the Moon would pass once round the Earth, if the Earth were at rest. For the *synodical* month, see LUNATION. The *solar* or *calendar* month is the time taken up by the Sun in passing through one of the signs of the Zodiac.

MOON. A secondary planet or satellite.

MULTIPLE STARS. Certain of the fixed stars, which appear single to the naked eye, are found, when examined by good telescopes, to consist of a system of two or more apparently bearing the relation to each other of a Sun

and planets; and the periods of some of these revolving systems have been partially ascertained. See Binary Stars.

NADIR. This is the point in which the line, supposed to be drawn through a spectator's position on the Earth's surface and its centre, would cut the celestial sphere on the other side of the Earth. The nadir of any spot on the Earth's surface is the zenith to the antipodal spot, and conversely.

NEBULÆ. (Latin, *mists.*) Bright spots in the heavens of different sizes, forms, and character, produced by clusters of stars, so situated as to appear very near each other; in some nebulæ, however, no stars are distinguishable.

NODES. (Latin, *knots.*) The points in which the orbit of a planet, comet, or satellite, cuts the ecliptic.

NODE, ASCENDING. That node in which the planet, &c., is when about to attain north latitude.

NODE, DESCENDING. That node in which a planet, &c., is when about to attain south latitude.

NODES, LINE OF. The imaginary line joining a planet's nodes.

NOON, APPARENT. The time when the Sun comes to the meridian.

NOON, MEAN. Twelve o'clock, as shown by a correct clock.

NUCLEUS. (Latin, *a kernel.*) A term used to express the bright stellar point of a comet.

NUTATION. (Latin, *a nodding.*) A periodic variation of the direction of the Earth's axis in space, occasioned by the action of the Sun and Moon on the equatorial parts of the Earth. The amount of nutation depends on the relative position of the Sun and Moon. The Moon causes the Earth's axis to describe a small ellipse, having its major axis directed towards the pole of the ecliptic.

NUTATION OF THE LUNAR ORBIT. A periodic variation in the angle of inclination of the plane of the Moon's orbit to the equator, produced by the spheroidal figure

of the Earth. It is the reaction of the nutation of the Earth's axis.

NYCTHEMERON. (Greek, *νυξ*, night, and *ἡμερα*, day.) A full day of twenty-four hours.

OBLIQUITY of the Ecliptic with the Equator, is the angle formed by their planes.

OCCULTATION. (Latin, *a hiding.*) When a star or planet is concealed from us by the body of the Moon, it is said to be occulted.

OCTANTS. (Latin, *eights.*) Points in the Moon's orbit between the syzygies and quadrature where the central disturbing force is zero. The octants are nearly at 55°, 125°, 235°, and 305°.

OPPOSITION. An aspect of any of the heavenly bodies, when 180° apart.

ORBIT. (Latin from *orbis*, a circle.) The imaginary curved line described in space by the centre of a body acted on by gravity and centrifugal force; the *mean* orbit is always a conic section, but the true orbit is constantly deviating from the mean, in consequence of the perturbations produced by the attractions of the other planets.

PARABOLA. A conic section, the cutting plane being parallel to a side of the solid; hence, the curve consists of one indefinitely extended branch, having a focus in its axis. The orbits of those comets which do not appear to return to our system, are considered as parabolas; that is, they are virtually such, for the small portion of them which we can observe the comet to trace.

PARALLAX. (Greek, from *παραλλαττω*, to transmute, to pass over.) *Generally*, the difference between the angles subtended by two points, when viewed from two separate situations. Hence, the *horizontal parallax* of the Sun, Moon, or planet, is the angle which the Earth's semi-diameter subtends at their centre, when they are at the horizon. When the Sun, &c., is not in the horizon, its parallax is the angle formed at its

centre, by two straight lines; one drawn to that of the Earth, the other to the point on its surface, where the spectator is situated. The *annual parallax* of a fixed star is the angle which the mean diameter of the Earth's orbit subtends at the star, and is apparently inappreciable.

PARALLELS OF LATITUDE, are circles drawn parallel to the equator on a terrestrial globe.

PENUMBRA. (Latin, *penè*, almost, and *umbra*, a shadow.) The light given out by the Sun when partially eclipsed, either to the Earth by the Moon passing before him; or to the Moon, by the Earth passing before him.

PERIGEE. (Greek, *about the Earth.*) The point in the orbit of the Moon, or of a planet, in which it is nearest the Earth.

PERIHELION. (Greek, *about the Sun.*) The point in a planet's or comet's orbit, when it is nearest the Sun.

PERIOD. (Greek, *about a way.*) Any length of time greater than those portions usually employed as measures of it.

PERIODIC TIME. That which a planet, comet, or satellite takes to complete a revolution round the Sun, or its primary.

PERIODICAL STARS. Certain of the fixed stars are so termed because they vary in their brilliance in definite periods of time. Some appear and disappear by turns, as is the case with *o* Ceti, *γ* Hydræ, *β* Persei, and others. This latter circumstance first led astronomers to form catalogues of the stars.

PERIŒCI. (Greek, περι, about, and οικεω, to dwell.) Those people who have the same latitude, but opposite longitude.

PERPETUAL APPARITION, STARS OF. Such as never rise or set.

PHASE. (Greek, *appearance.*) The variation in the quantity of the enlightened hemisphere of the Moon that

is seen from the Earth, occasioned by the Moon's change of place relatively to the Sun and Earth.

PLANE. (Latin, *smooth.*) An imaginary surface, which, when supposed to pass through the centres of the Earth and other bodies, and extended to the heavens, is called the plane of a planet's orbit.

PLANETS. (Greek, πλανητης, a wanderer.) Heavenly bodies, which move round another, as their centre of motion. *Primary* planets are such as move round the Sun, as a centre: *secondary* planets are moons, which move round their primary planet.

POLAR CIRCLES. These are two small circles, $23\frac{1}{2}°$ from the Poles. The northern is called the *arctic* circle, and the southern the *antarctic.*

POLAR DISTANCE, is an arc of a meridian between the centre of the object and the pole of the equinoctial.

POLARIS. The name given to α Ursæ Minoris, as being the star at present nearest to the pole, or nearest in the line of the earth's axis indefinitely prolonged in space.

POLE. (Greek, from πολεω, to turn.) The points on the surface of a sphere which are the extremities of the diameter the solid is supposed to revolve on; and also the imaginary points of the celestial sphere through which the axis of rotation of the Earth or other planet would pass, if indefinitely produced.

POLES, of any Great Circle of a Sphere, are the two points in which a diameter perpendicular to the plane of that circle, cuts the surface. Hence, the poles of a great circle are at 90° distance from every point in its circumference.

PRECESSION. (Latin, *going before.*) The Sun, Moon, and planets' attraction of the equatorial parts of the Earth causes a secular fluctuation in the inclination of the equator to the ecliptic; the mean result is, that the line joining the equinoctial points retrogrades on the

plane of the ecliptic; this motion is called the *precession of the equinoxes*, and the line would complete a revolution in the ecliptic, in 25868 years.

PRIME VERTICAL. That azimuth circle which passes through the east and west points of the horizon.

QUADRATURE. (Latin, *a quarter.*) That aspect of the Moon, when half of her illuminated surface is turned to the Earth.

QUARTILE. An aspect of the planets, when they are 90° or a quarter of the Zodiac apart.

RADIUS-VECTOR. (Latin, literally *carrier-radius.*) The straight line drawn from the centre of the Sun to that of a planet, or from the centre of a planet to that of its satellite, when both revolve round a common centre of gravity, and reciprocally act on each other by gravitation.

REFRACTION. (Latin, *bending back.*) A distortion of the rays of light in passing through a new medium. Hence, the heavenly bodies, viewed obliquely through the atmosphere, appear at a greater height than they really are.

RETROGRADE. An apparent motion of the planets in some parts of their orbits, when they seem to go backwards, or contrary to the order of the signs.

REVOLUTION. The motion of a planet in its orbit round the Sun or its primary, in contradistinction to its *rotation* on its axis.

REVOLUTION, TROPICAL. The consecutive return of a planet to the same equinox or tropic.

REVOLUTION, SYNODIC, of the Moon. The interval between two consecutive new or full moons.

RHUMBS. These are the divisions of the horizon into thirty-two parts, called also the *points of the compass:* each point contains $11\frac{1}{4}°$.

ROTATION. (Latin, *turning on a wheel.*) The motion of a solid on an axis, used to distinguish the *diurnal* motion

of a planet on its axis from its annual *revolution* in its orbit.

SATELLITE. (Latin, *an attendant, or parasite.*) The name given to those secondary planets which revolve round certain of the primary ones of our system. The Moon is the satellite of the Earth.

SECONDARY CIRCLES of the Sphere, are such as pass through the poles of some chief Great Circle.

SEXTILE. An aspect of the heavenly bodies, when they are 60° distant from each other.

SIGN. Formerly the ecliptic was divided into twelve equal divisions of 30° each, commencing at the equinoctial point, in consequence of the twelve signs of the Zodiac; but this division is now abandoned, and the degrees are numbered from 0 to 360, without any higher division.

SIGNS OF THE ZODIAC. Twelve constellations lying near the plane of the ecliptic, through some part of which, therefore, the Sun appears to pass in succession during his annual course. The names of these signs, and the characters used in astronomical works to express them, are as follow. (See Aries.) Aries, ♈; Taurus, ♉; Gemini, ♊; Cancer, ♋; Leo, ♌; Virgo, ♍; Libra, ♎; Scorpio, ♏; Sagittarius, ♐; Capricornus, ♑; Aquarius, ♒; Pisces, ♓.

SOLSTICE. (Latin, *the standing still of the Sun.*) The time when the Sun arrives at either of the solstitial points, and seems for some days to vary neither in declination, nor in meridian altitude.

SOLSTITIAL POINTS. These are the two signs of the Zodiac, Cancer and Capricorn, at which the ecliptic touches the Tropics, and into which the Sun enters on our longest and shortest days: they are, therefore, the higher and lower parts of the ecliptic.

SOUTHING. A term applied principally to the Moon, to express her coming to the meridian.

SPHERE. (Greek.) A geometrical solid, produced by the revolution of a semicircle about the diameter. The great circles which are assumed as subtending the angular distances of the heavenly bodies, and those circles which are the projections of their various orbits, are referred to an imaginary sphere which is represented by the ordinary celestial globes.

A *right* sphere is that position of the Earth, when the equinoctial passes through the zenith and nadir, the poles being in the horizon. A *parallel* sphere is when the horizon coincides with the equator, the poles being in the zenith and nadir. An *oblique* sphere is when the horizon cuts the equator obliquely.

SPHEROID. A geometrical solid, produced by the revolution of an ellipse about an axis: the spheroid is called *oblate* when the conjugate axis is that on which the rotation is made; and *prolate* when the rotation is made about the transverse axis of the ellipse.

STARS. The countless, luminous bodies that are scattered throughout space; most of which are, probably, the centres of planetary systems, like that of which our Earth is a member. The Sun is hence considered as a *fixed* star, as these bodies are termed, in contradistinction to the planets, &c., which revolve round them. There are many stars which, to judge by their light, as far exceed our Sun in magnitude, as the planet Jupiter exceeds the Earth.

STATIONARY. That state which a planet is in, when it has no apparent motion.

STYLE. A manner of reckoning time: also the shadow-producing part of a dial.

SUN. The star that constitutes the centre of our planetary system, and by whose attraction the planets are kept revolving round it.

SUPERIOR PLANETS, are those whose orbits are without the orbit of the Earth: they are also called *exterior*.

SYSTEM. A number of heavenly bodies revolving round a common centre.

SYZYGY. (From Greek, *συν*, together, *ζυγος*, yoke.) A planet, but more commonly the Moon, is said to be in syzygy, when she is in *conjunction* or *opposition;* that is, when she is *new* or *full.*

TELESCOPIC STARS. Are those stars which are only discoverable by means of a telescope.

TIDES. Risings and fallings of the waters of the Earth, in consequence of the attractions of the Sun and Moon. *Spring* tides are such as are occasioned by the joint attraction of the Sun and Moon: *neap* tides result from their attractions mutually opposing each other.

TIME, TRUE SOLAR, is measured by the consecutive return of the Sun to the meridian of any place.

TIME, MEAN SOLAR, is estimated by the return to the same meridian, of an imaginary sun supposed to move in the equator with an equal mean motion. See Day.

TIME, EQUATION OF. The difference between mean and apparent time.

TIME, SIDEREAL, is estimated by the consecutive apparent return of the Sun to the meridian of the same fixed star. See Day.

TIME, APPARENT SIDEREAL, is estimated by the transit of the equinoctial point at any place, and is variable owing to the effects of precession and nutation.

TRANSIT. (Latin, from *transeo*, to pass over.) The passage of one of the inferior planets across the disk of the Sun is so termed: also, the apparent passage of any heavenly body across the meridian of a place, in consequence of the Earth's diurnal motion, is termed its transit, when it is observed through a telescope so mounted that its line of collimation shall lie in the plane of that meridian.

TRINE. An aspect of the planets when they are 120° from each other.

TROPICS. (Greek, from τρεπω, to turn.) The points in the ecliptic where the Earth is situated, when the Sun lies in a plane passing through the Earth's axis perpendicular to the plane of the ecliptic. These points are so called because the Sun, when he arrives at them in his *apparent* annual course, seems to *turn* again towards the equator.

TWILIGHT. A faint light which we perceive before the rising of the Sun, and after his setting; owing to the Earth's atmosphere refracting the solar rays.

UMBRA. (Latin.) A *shadow* cast by a heavenly body.

VARIATION. A name given to certain perturbations: that of the Moon is an alternate acceleration and retardation of her motion in longitude when she is in quadrature, owing to the attraction of the Sun acting in a line *tangential* to her orbit.

YEAR. (Teutonic, Jär.) The portion of time in which a primary planet performs a revolution in its orbit round the Sun.

YEAR, ANOMALISTIC. The time intervening between two successive passages of the Earth through an aphelion or perihelion: it is longer than the sidereal year by the time the Earth takes to move through the space the line of the apsides has advanced, owing to precession.

YEAR, CIVIL, consists of an exact number of days, an allowance being made at certain recurring periods for the fraction of a day neglected in the ordinary reckoning.

YEAR, JULIAN. The year according to the Old Style, or as settled by Julius Cæsar.

YEAR, SIDEREAL. The time occupied by the Earth in its revolution from any point in its orbit, till its return to the same; that point being determined by a line drawn from the Sun's centre to any fixed star that lies in the plane of the ecliptic. The sidereal year is equal to $365^d\ 6^h\ 9'\ 9{\cdot}6''$.

YEAR, TROPICAL. The time taken by the Earth to move in its orbit from the vernal equinoctial point till it returns to the same again; it is equal to $365^d\ 5^h\ 48'\ 49{\cdot}2''$.

ZENITH. This is generally the point in which a diameter to the Earth, passing through a spectator's position, cuts the celestial sphere over his head. But since the Earth is not a spherical body, the Zenith of any point, more correctly speaking, is the point in which the celestial sphere is cut by a line from that point, which line is perpendicular to the tangential plane at the same point. The *zenith distance* is the arc of a vertical circle, between the centre of a heavenly body and the zenith. It is what the altitude of the body wants of 90°.

ZODIAC. (Greek, ζωδιακος, from ζαω, to live, on account of the *animals* of the constellations comprised in it.) A zone of the celestial sphere comprised between two small circles, one on each side of the ecliptic, at equal distances from, and parallel to, it. The orbits of nearly all the primary planets lie within this zone. It is 16° broad, and is divided into two equal portions by the ecliptic.

ZODIACAL LIGHT. A luminous appearance observed at certain periods, near the Zodiac, about sunrise or sunset.

ZONE. (Greek, *a band.*) A division of the sphere, contained between any two parallels of latitude. On the terrestrial globe are reckoned *five* zones:—one torrid, two temperate, and two frigid.

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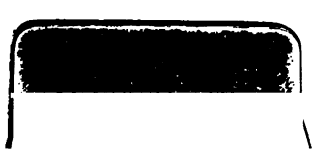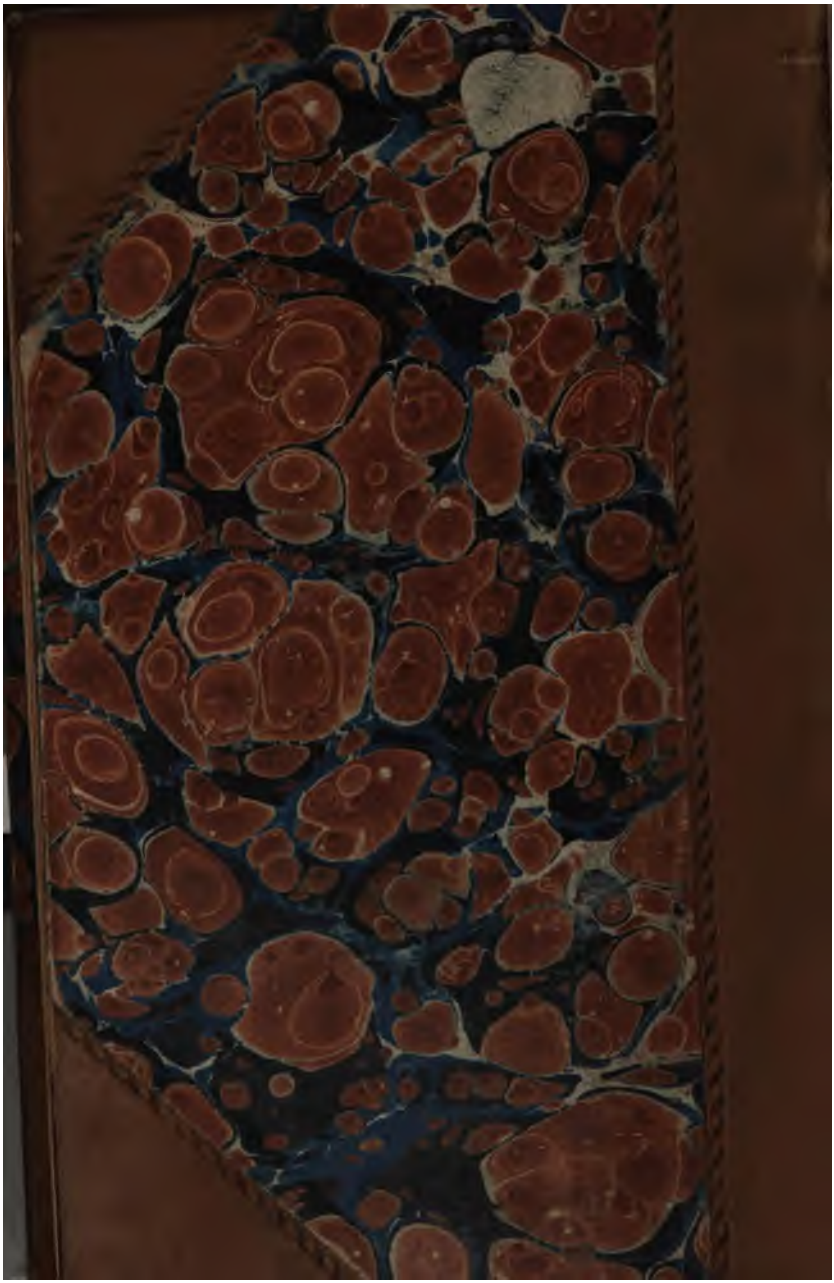
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